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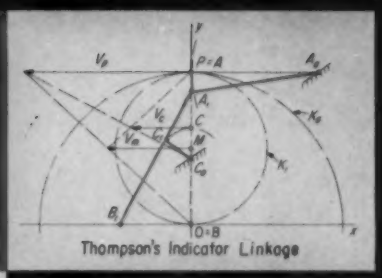
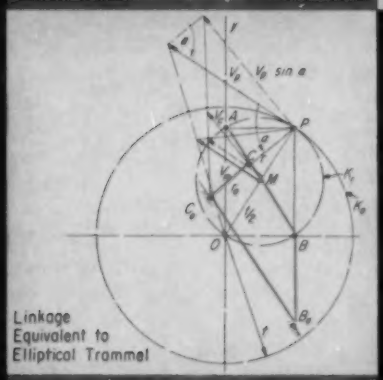
PRODUCT ENGINEERING

McGRAW-HILL WEEKLY OF DESIGN, RESEARCH AND DEVELOPMENT · APRIL 4, 1960

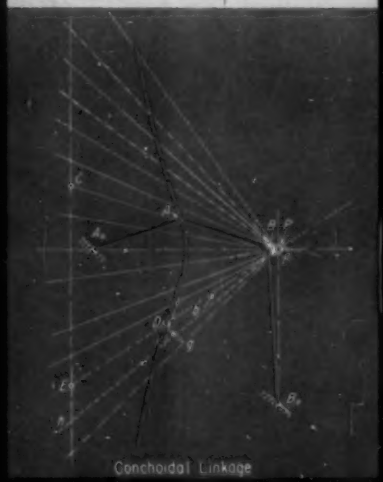
Evan's Linkage



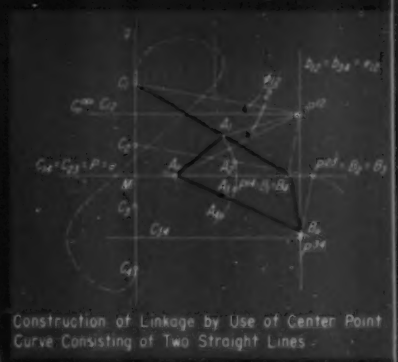
Thompson's Indicator Linkage



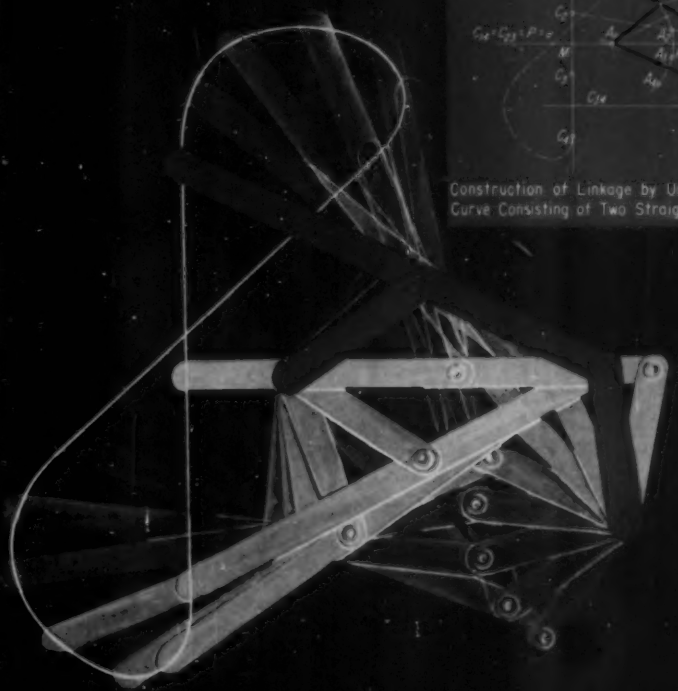
Linkage Equivalent to Elliptical Trammel



Conchoidal Linkage



Construction of Linkage by Use of Center Point Curve Consisting of Two Straight Lines



four-bar linkages for STRAIGHT-LINE MOTION

see page 3

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McGRAW-HILL WEEKLY OF DESIGN, RESEARCH AND DEVELOPMENT

April 4, 1960 Vol. 31, No. 14

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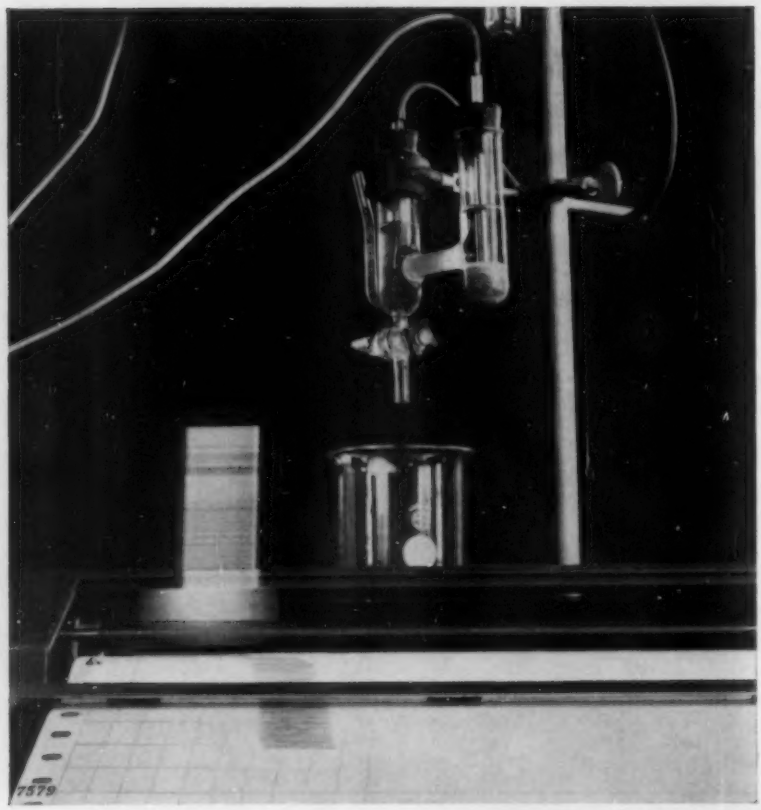
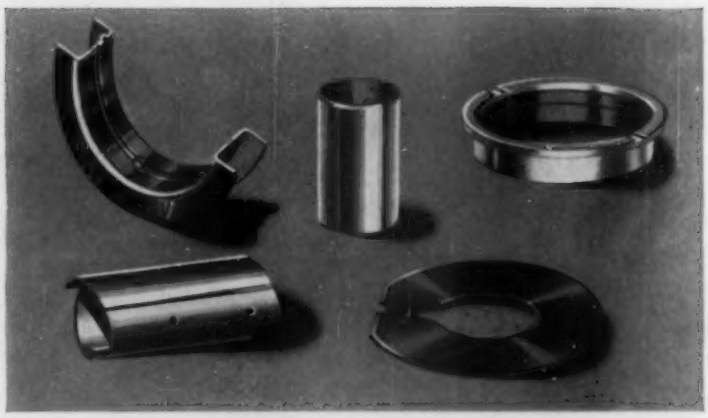
ANALYTIC "BLOODHOUND" SNIFFS OUT SECRETS OF BEARING CORROSION



WE USE THIS HYPERSENSITIVE DEVICE TO TRACK DOWN ENGINE BEARING CORROSION TO ITS SOURCE. This instrument needs only a minute fragment of metal for accurate analysis. Consequently, engine bearing corrosion can be traced from its beginning through complete destruction of the bearing surface. Because test variables are minimized, Federal-Mogul engineers can accurately relate degree of corrosion to specific engine operating conditions. This analytical tool is in continual use in our laboratory, assisting research on many different projects. Prevention of corrosion and development of new bearing alloys are high on the list!

SUCCESSFUL BEARING PERFORMANCE depends on selecting the proper alloy for the operating conditions to be met. Federal-Mogul engineers have had years of experience with bearings and applications of all kinds . . . and this wealth of knowledge is available to bearings users. This is one reason why F-M sleeve bearings, precision thrust washers, formed bushings, and low-cost spacers are chosen for use in virtually everything from baby buggies to heavy industrial cranes.



There's much valuable data in our Design Guides on sleeve bearings, thrust washers and bushings; and in our brochure on spacers. For your copies, write Federal-Mogul Division, Federal-Mogul-Bower Bearings, Inc., 11043 Shoemaker, Detroit 13, Michigan.

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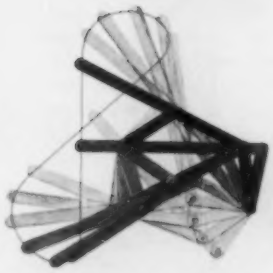
INTERESTING TO NOTE

Straight-line Linkage



The linkage on our cover (and p 37) traces two straight lines aimed in different directions. The lines are joined at top and bottom into a graceful figure-8. It is interesting to realize that you can't drive this linkage through the complete 8 from any single point on the linkage proper. You can drive it at the tracing extension without locking. We're sure of this—our art director made a cardboard model and we've been playing with it at odd moments ever since.

You've Got to Have Change

Americans love machines. This was one impression received by many of the Olympic athletes this past February. Sven Laftman, vice-president of the International Skating Union, thought the American adherence to a mechanical way of doing things had gone to ridiculous extremes. Said Laftman, "Last night some visiting speed-skating officials asked the organizers to try to eliminate some cracks on the ice. When they came back this morning the cracks were still there, but covered by a thin layer of ice. When the skaters complained to the organizers, they got the answer that the machines couldn't repair it. The visiting leaders suggested fixing the surface manually. Someone grabbed a pail of water and the cracks finally were eliminated." According to Laftman, "Americans believe too much in machines."

This is probably true. How often has the ever-efficient housewife gone without the breakfast toast because the electric toaster wasn't operating? But, if we've taken machines for granted, we've also taken quite a step since our inventive forefathers tried to convince deaf ears that the horseless carriage was more than a toy. As Arthur D Little Inc's former president, Raymond Stevens, says on page 24, "Blindness to the inevitability of, and the need for, change is most serious."

Huck Finn—Englishman

Whether for labeling parts (p 48), or settling literary questions, identification is important. This has led to endless controversies among scholars of the printed word; each as ridiculous as the last. Now, added to the famous Shakespeare-Bacon controversy, comes the question of Huckleberry Finn's nationality. Recently the New York *Times* said, "It is one of the smaller ironies of English literature that Huckleberry Finn, the most American of books, was first published abroad: by the House of Chatto & Windus of England, 75 years ago." This started the row.

The first copies of the book did appear in England before any were sold in America—but only by a strange quirk. The publisher's original plan was to issue both American and British editions before mid-December of 1884, in time for the Christmas trade. But a playful

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engraver altered one of the American plates, turning an innocent illustration into an indecent picture. Before the alteration was discovered, 30,000 copies of the book came off the presses. The offending pages were snipped from bound copies and new ones pasted on the stubs. However, all this took time. Meanwhile, the plates in England turned out the book on schedule, allowing Huck Finn to be read abroad first.

Most people don't care where Huck Finn first appeared, as long as he endures. When it first appeared, the book was banned by the Concord Library, which termed it "the veriest trash." Mark Twain then gleefully predicted "it will sell 25,000 copies for sure." His estimate was a little conservative—nearly 10 million copies already have been sold.

Air Has Ups and Downs, Too

When the alchemists conceived their "elements," it was only natural that air be included. Aristotle, too, held the idea that the universe was composed of earth, water, air, and fire; but he thought they were in four concentric shells, with earth innermost and fire outermost. As for the question of weight, since Aristotle couldn't feel the weight of air, he said it was weightless, a view that was accepted for almost 2000 years.

Galileo was the first since Aristotle to question the weightlessness-of-air theory, but he died before his research went very far. However, one of his students, Evangelista Torricelli, carried on the investigation. His curiosity was spurred by Galileo's finding that an ordinary water pump drawing water out of a well would not lift the water any higher than about 33 feet. Torricelli reasoned that Aristotle must have been wrong—air must be the force preventing the pump in the back yard from lifting the water higher. To test his theory, he took the densest liquid he could find, mercury, and reasoned that if 33 feet of water would be balanced by the weight of air, it would take only 30 inches of mercury to equal the density of the water (mercury is about 13.5 times as dense as water). To be sure, Torricelli's theory proved correct, but he noticed something else. The mercury didn't remain constant at the 30-in. mark, but moved up or down a little now and then. Not only had Torricelli proved air had weight; he also had invented the barometer.

Some of our current calculations of air and its effects upon design appear in the article on page 52.

—Benedict A Leerburger Jr

SIDELIGHTS

The newer remote-control television sets have had some problems from completely unexpected sources. Normally they're switched by an ultrasonic (40,000 cps) signal from a tuning fork in the controller. Now we read news reports of a hospital patient who nearly had a relapse when his TV set turned on at the first hiss of a small air freshener aerosol can. Hi-fi addicts have had similar experiences when violin solos squeaked through their tweeters. Of course they took this as proof of excellence. How many fans can boast of a system that can handle 40,000 cps?

NEXT WEEK IN PRODUCT ENGINEERING

. . . Design by Digital Computer

There are now ten such computers on the market—including six, brand-new, fully transistorized machines announced in the last six months. This 16-page special report will tell how to choose and operate the new desk-size problem solvers.

. . . Unique Chart Maps Resilience Modulus

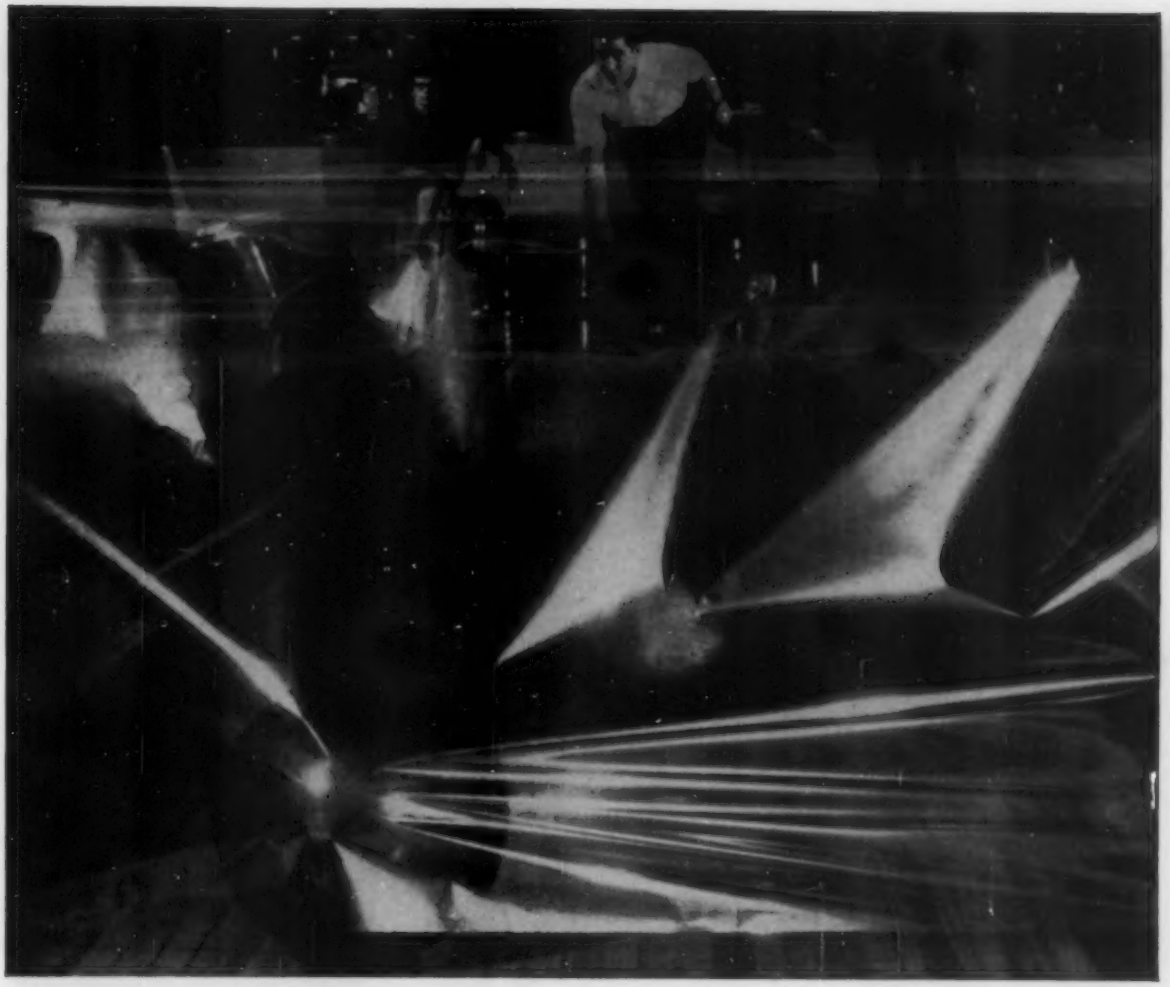
Multipurpose graph simultaneously relates and compares structural properties of any material.

. . . Standards for Metal Hose

Two new methods—now being studied by ASME—introduce uniformity into the choice of corrugated or interlocking hose.

. . . Should a Young Engineer Be Started "On the Board."

Four engineering executives offer their points of view.



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DEVELOPMENTS TO WATCH...

Planes to make fuels as they fly?

Can the problem of fuel deterioration under heat be solved by developing compounds that will use waste engine heat to create fuels rather than destroy them? The Air Force thinks maybe so; and it's exploring several approaches to such "endothermic" fuels. There's an extra incentive: Such fuels would not only get around the deterioration problem but would also serve as a heat sink to remove waste heat.

Three types of compounds are under development:

- Hydrocarbons (cetane, for example) that will undergo thermal cracking at the desired temperature (currently, 800 F).
- Naphthenes and related compounds that can be dehydrogenated to aromatic compounds—toluene, for instance.
- Compounds that will form free radicals that will, in turn, burn readily in the presence of air. An example of this type is 1,4-dimethylcyclohexane.

Much work remains to be done—finding suitable compounds and catalysts, developing reactor systems, and so on. But Wright Air Development Center's Propulsion Laboratory believes the idea is a valid one and well worth further study.

Make-your-own vacuum tubes designed in Bermuda

Vacuum tubes that can be put together in an ordinary laboratory—without complex welding, baking, and evacuating equipment—have been designed by J. Owen Harries of Bermuda. Primary aim was a kit for students. But the tube design incorporates a number of interesting ideas.

The most important innovation is the evacuation technique.

Two methods are suggested: One uses activated charcoal, heated to absorb the gas, then cooled with dry ice. The other method requires a pump—but only a small mechanical one of the type found in most labs.

These methods do the "heavy" work—the first step of the evacuation.

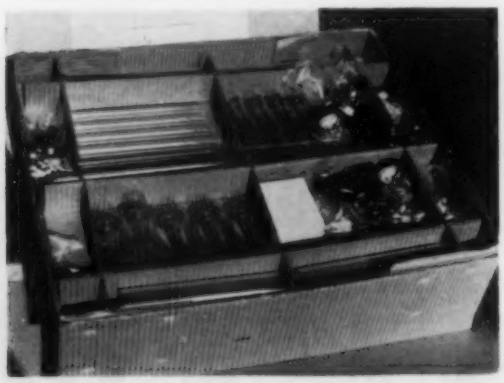
Then a barium-aluminum alloy and a titanium "getter" are evaporated in the vacuum tube (by passing a heating current through wires sealed in the tube) to obtain the ultimate vacuum.

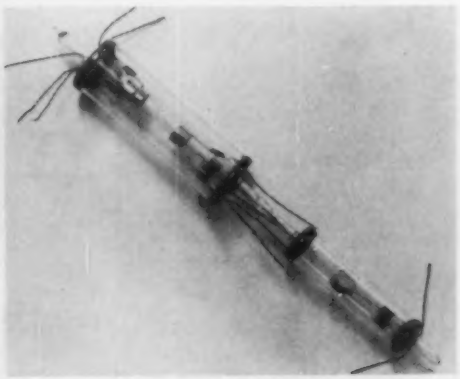
These other innovations simplify assembly:

Glass tubes are joined to other glass parts with a powdered-glass solder, so there is no need for glassblowing know-how.

Electrodes are designed for clamping instead of welding—again eliminating need for special equipment and techniques. A pair of pliers and a screwdriver replace the spotwelding, says Harries.

The kits are not yet commercial, but Harries believes they can be produced for about $30. Several prototypes are now on test.





VACUUM TUBE KIT contains all necessary parts to make triodes and electron beam tubes like the one shown here. In the tube, the electron gun, fluorescent target, and getters are at the left; connections for a vacuum gage at the right.

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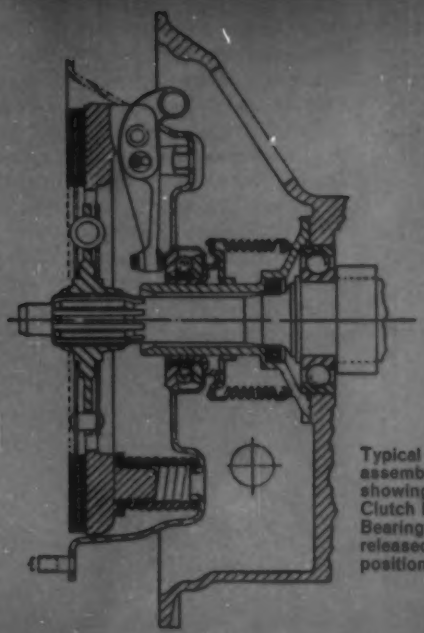
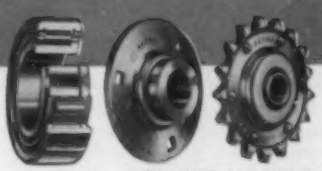


Typical clutch assembly showing Aetna Clutch Release Bearing in released position.



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ANTI-FRICTION SUPPLIERS TO LEADING ORIGINAL EQUIPMENT MANUFACTURERS SINCE 1916

New paper for electrical insulation

A vegetable parchment paper with an "etched" surface that prevents coils from slipping is being introduced by Paterson Parchment Paper Co specifically for use in coil winding applications. The paper is said to have a dielectric strength of 321 volts/mil in 2-mil sheet and to be suitable for use in Class A insulation (to 220 F). It's also claimed to have good abrasion resistance and built-in wet strength so it can accept encapsulating resins without marked loss of tensile or insulating properties.

(Note: For more on paper for electrical and other engineering uses, see *PE—Feb 16 '59, p 50*)

Electroplating key to new bonding system

To replace difficult soldering operations, Allied Research & Engineering has developed an electroplating system which in effect, forms a tight metal collar around the parts to be joined.

The first application for the process is in attaching flanges to Invar tubing. The parts are first assembled—by press fit—then masked so only the joint area is exposed. Electrodeposition of copper or nickel, in whatever thickness is needed to obtain the required strength, then completes the job. Plating is done at room temperature, thus avoiding problems of warping encountered in the soldering operation.

New data on light-metal corrosion

High-strength aluminum and magnesium-thorium alloys are being tested for corrosion resistance by Martin-Denver in a long-term program aimed at finding the best combination of base materials, coatings, and fasteners for missile and other applications.

Both coated and uncoated samples, stressed and unstressed, are undergoing atmospheric and salt spray tests.

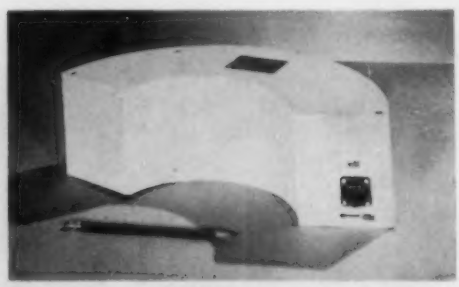
The tests have only been underway for a few months, but results are encouraging. Both stressed and unstressed 2014-T6 aluminum sheet specimens show less corrosion than expected—even in samples stressed to within 25% of yield strength. The same is true for welded materials, though the latter show greater susceptibility to corrosion than unwelded metal, as would be expected. Corrosion in a salt air atmosphere (at Cape Canaveral) was considerably greater, however, than in dry air (at Denver).

Thus far, painted surfaces have shown complete freedom from attack, and intergranular attack on samples protected by chromate conversion coatings has been negligible. Likewise, reduction in tensile strength has averaged only about 6% after 9 months' exposure.

On the magnesium-thorium alloy, epoxy coatings are providing good protection, with one-coat finishes on the clean, bare metal apparently more effective than 3 coats of primer on metal with a #17 finish.

Shaped-to-fit batteries provide dual output

To operate equipment that requires two voltage levels, Cook Batteries has designed a dual, packaged unit, shaped to fit the equipment it supplies. Designed for activation (in 1 sec) by a solid-propellant gas generator acting on an electrolyte tank-and-piston arrangement, the package shown here incorporates one 8-amp, 28-v battery and one 3-amp, 6.3-v unit. It weighs 13 lb, and is hermetically sealed. Other shapes and sizes can be supplied, however. Fail-safe detection circuits can also be built in to prevent premature activation. —ARG



PACKAGED BATTERY incorporates two power units, designed for independent, automatic activation. Shape and size can be varied to meet specific equipment needs.

WHAT'S HAPPENING IN RESEARCH . . .

Explosions concentrate magnetic fields

Magnetic fields in the 10- to 15-million gauss range are being created with the aid of high explosives at the AEC's Los Alamos Laboratory; and that's only a starter. Equipment now under construction is expected to produce fields on the order of 20 million gauss over a radius of 4 mm with a duration of at least a microsec.

Purpose of the explosives is to compress and instantly contain a smaller (100,000-gauss) flux, produced by a condenser bank, building up the magnetic intensity much as one would build up pressure.

The apparatus consists of a copper or brass tube (¼ in. thick, 3 in. dia, and about 3 in. long) in which a slot has been milled to form an open circuit for the induction of the initial magnetic field. This slot is so placed that it is closed by the explosion, turning the tube into a perfect conductor to trap the flux as the explosion collapses the tube.

Calibrated pickup probes, leading to a firing bunker, are used to measure the field, and LASL scientists believe the final measurements accurate within about 15%.

Carbon resistors measure ultralow temperatures

Tests of 100-ohm, 1/10-watt commercial resistors show them to be both stable and accurate in the liquid hydrogen range (minus 425 to minus 360 F), say NASA researchers. A. C. Herr, H. G. Terbeek, and M. W. Tiefermann of Lewis Research Center report these carbon-composition resistors have high thermal sensitivity and a relatively low resistance that results in a satisfactory impedance for instrumentation. Too, their small size is well suited to mounting in test apparatus. Accuracy is on the order of 1% of the absolute temperature.

Test procedures and circuitry are outlined in NASA Technical Note D-264, now obtainable from that agency.

New light on tire-cord failure

Loss of strength in tire cord fibers is not a primary cause of fatigue failure in tires, reports from Fabric Research Laboratories Inc of Dedham, Mass, indicate.

In tests of tires removed from taxis after service periods ranging up to 100,000 miles, FRL found an initial loss of cord strength of 10 to 15% in the first 20,000 mi, and then a very slow diminution in strength of the cord. But the fibers themselves showed no corresponding loss. While there did seem a small decrease in fiber strength with mileage, it was apparently insignificant and was not a cause of fatigue failure.

Fatigue failure seems traceable almost entirely to localized filament breakage—in some cases, at least, resulting from stresses set up by localized bond failure.

The problem, says FRL, is a lot more complex than it originally seemed and needs much more study.

briefs . . .

Lab reports on transistors, available without charge from Lansdale Div, Philco Corp, Lansdale, Penna, are listed in a 12-page index just issued by the company. The reports cover alloy and diffused-base transistors for low and medium power frequencies, pulse amplifiers, and such special types as Philco's own Humistor.

Liquid nitrogen and hydrogen are stepping-stones to ultralow temperature in a system under test at the NBS Boulder, Colo, Labs. They're using a liquid-nitrogen precooler to reach −340 F and then a hydrogen "refrigerator" to maintain −422 F in the evaporator of a helium-gas circuit. Liquefaction of the helium goes the rest of the way—to −452 F. The result: a considerably simplified system, firm control of temperature, and a device that can be arranged to produce liquid helium for either closed-system or external use. The Boulder research team has prepared a report (NBS Technical Note 39) containing system diagrams and heat-transfer data. Copies may be obtained from OTS, Dept of Commerce, Washington 25, DC. Price: 50¢. The OTS number is PB 151 398. —ARG

Recording spectrophotometers at ½ price

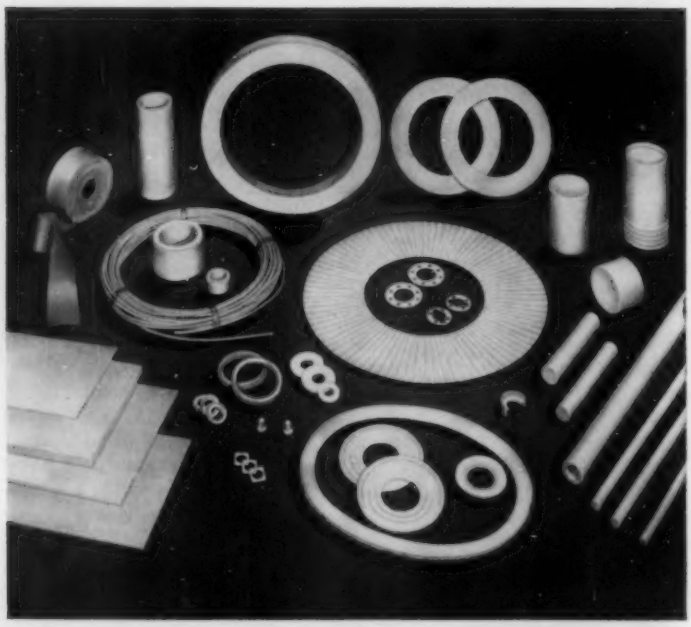
A recording spectrophotometer that can be sold at "up to 50% lower than other recording instruments" has been announced by Bausch & Lomb Optical Co. And, says B & L, it features automatic wavelength speed control (with an electronic "brake" that goes into operation when a complex spectrum appears), external dual lamphouse, aircooled hydrogen lamp, built-in wavelength calibration, and a large sample compartment.

Key to lower cost is "building block" design, which also simplifies removal and replacement of major components and accessories.

B & L says it operates throughout the ultraviolet and visible range (200-700 mμ) and has a new monochromator which gives "up to 10 times" greater dispersion in the visible range than quartz prism instruments. Base price is $3685.

BUILDING BLOCK DESIGN simplifies spectrophotometer construction. Unit weighs only 180 lb, occupies a space 36 by 22 by 15 in.

PLASTICS
in Design
Engineering



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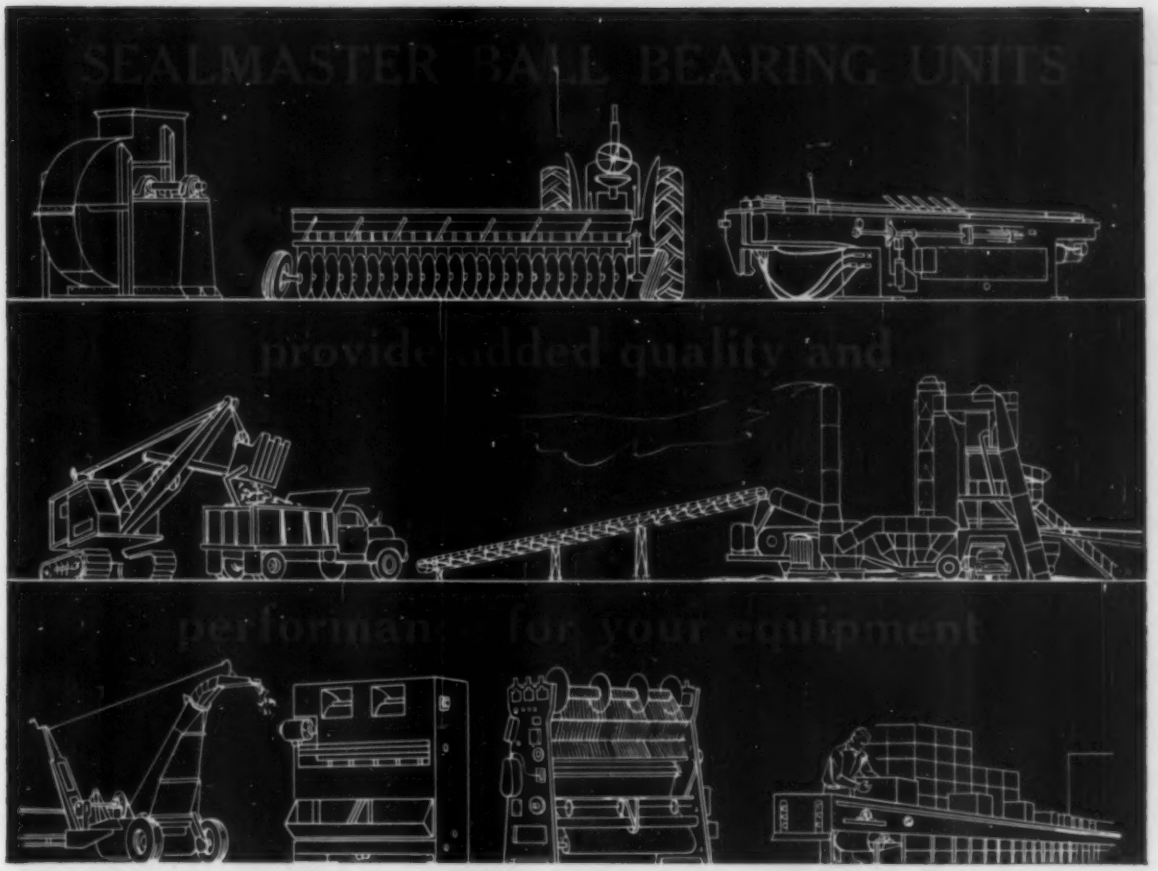

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FROM WASHINGTON . . .

Lag in Materials Development Slowing US Space Efforts

The lag in materials developments is holding back the development of better missiles, rocket motors, naval vessels, electronic devices and nuclear propulsion systems. **This is the warning in a new report from the National Academy of Sciences–National Research Council.**

The report, "More Effective Organization and Administration of Materials Research and Development for National Security," was nearly a year in preparation. Chairman of the academy committee is Dr Clyde C. Williams, formerly president and director of Battelle Memorial Institute.

Six major recommendations are made for breaking through the "materials barrier." They are: **Give top government priority** for training of materials scientists and engineers. **Recognize programs for improved materials** for national security uses in their own right. **Centralize responsibility for materials research in each government agency** and enlarge the working and central staffs. **Offer government incentives to stimulate research and development on new and improved materials.** Included in this would be a provision for adequate facilities where such development is for national security purposes. **Review the supply-demand situation at least once a year on a 5 to 10-year projected basis.** And, where a shortage is predicted, develop programs to obtain the materials. **Speed up and improve the dissemination of technical information.** And have the government give "broad support" to universities for training materials engineers and scientists.

Navy Polaris program at critical stage

The Navy is pulling out all stops to demonstrate that its Polaris submarine program should be speeded up. **Technically and politically, the program is at its most critical point.** Technically, the missile program is at the point of firing combat-type missiles. Tests of the various components of the 1200-mi solid-fuel missile, whether successes or failures, don't carry the same importance as full-scale firings.

If the Polaris missile performs as well as the Navy has claimed it can, then Congress seems ready to vote money to speed up the program. It offers a good chance to plug the so-called missile gap and give the US a stronger retaliatory force–a point Navy is talking up strongly. The next few weeks will be the telling period.

Tax relief proposed for consulting engineers

Consulting engineers may get tax relief to set up retirement-pension programs. But, the measure is no certainty. **Congress is taking a somewhat liberal approach to the issue.** The Administration, in its budget-conscious mood, is providing some stumbling blocks. It wants a more conservative approach.

The House of Representatives has already passed a bill that would allow all self-employed persons to deduct 10% of their income–with a $2500 ceiling–each year to set aside in approved pension programs. The Administration doesn't want to be quite this liberal. It is working on an alternate program that would require all self-employed persons to extend such a retirement program to their employes as well. It would mean that they would have to foot part of the employe's pension program, and this could hold down the program's use.

Chances for approval of some type of self-employed-persons pension program are about 50-50 this year. Right now, Congress is awaiting recommendations from the Administration before it moves ahead on the issue.

For the engineer who refuses to stagnate

HALF the world is half asleep! Men who could be making *twice* their present salaries are coasting along, hoping for promotions but doing nothing to bring themselves forcefully to the attention of management.

They're *wasting* the most fruitful years of their business lives . . . throwing away thousands of dollars they may never be able to make up. And, oddly enough, they don't realize—even remotely—the tragic consequences of their failure to forge ahead while time is still on their side.

Engineers and other technically-trained men are particularly prone to "drift with the tide" because their starting salaries are reasonably high and promotions come at regular intervals early in their careers. It isn't until later—too much later in many cases—that they discover there is a definite ceiling on their incomes as technicians.

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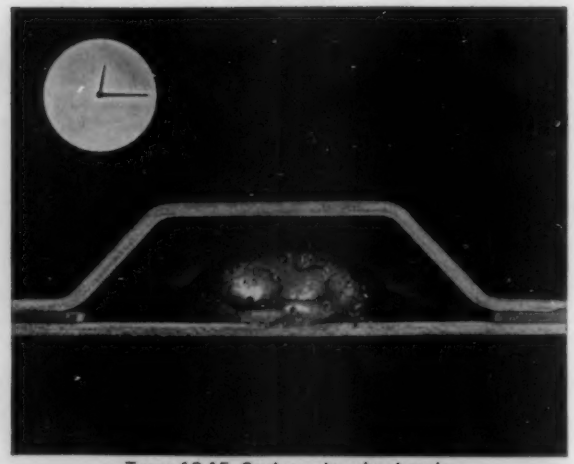
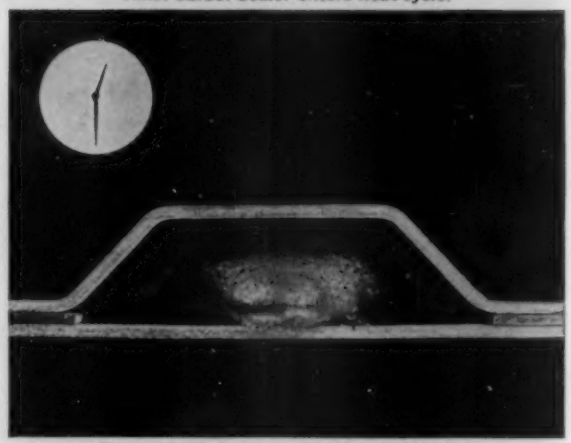
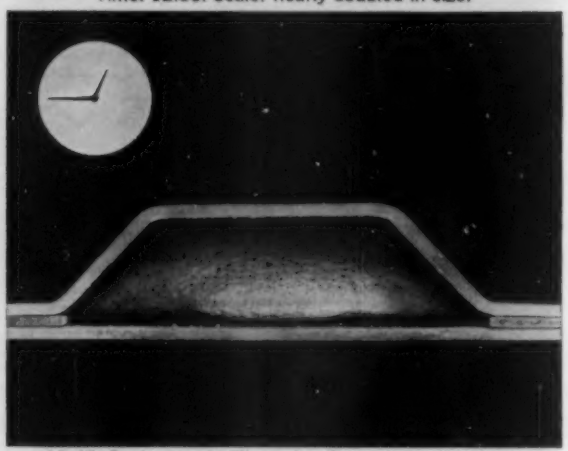


Time: 12:15. Sealer enters heat cycle.



Time: 12:30. Sealer nearly doubled in size.



12:45. Sealer nearly fills cavity. Time elapsed: ½ hour.

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. . . WHERE RESEARCH IS THE KEY TO TOMORROW

3M COMPANY

THE ENGINEERING WEEK

Leipzig Fair dominated by Red China and East Germany. Russia's own display is weak in comparison. On-the-spot report indicates:

- **East Germany is promoting Leipzig as international center of machine-tool engineering.**
- **US firm sells equipment but East German dollars unavailable for payment.**
- **West German and British exhibits best of Western bloc of nations.**
- **Leipzig claim of $1 billion in sales may be exaggerated.**
- **Underdeveloped countries are impressed by Soviet-bloc equipment.**

RED CHINA. The "Red Flag", a 4-stroke, V-8 engine rated at 245 hp at 4400 rpm, gives this first Chinese passenger car a reported top speed of 112 mph. Fuel economy is claimed to be 22.4 mpg.

Soviet-bloc Machine Tools Score Hit at East German Trade Show

LEIPZIG—East Germany's big spring fair this year startled many with machine-tool exhibits from the supposedly agricultural countries of the Russian bloc of nations. In previous years, the Leipzig spring fair has been dominated by Russian and Western exhibits; but this year Bulgaria, Hungary, Rumania, and Red China showed machine tools, machinery, consumer products, and even automobiles. The big surprise was the "Red Flag"—a Chinese-designed V-8 limousine featuring a big 5.65-liter engine and a windshield deeply curved at the top and sides. However, focal point of the Chinese exhibit was the machine-tool and machinery section.

As in previous shows, many items appeared to have been copied from the Russians. This time, however, products showed evidence of appearance design—a notable lack in the past.

Two items were definitely of Chinese design—a centerless semiautomatic internal grinder, and a key-way miller. Technical visitors believed the Chinese items to be more industrialized than in the past, although sloppy plumbing, with hoses and connecting feed lines exposed or left dangling, was still in evidence on machines.

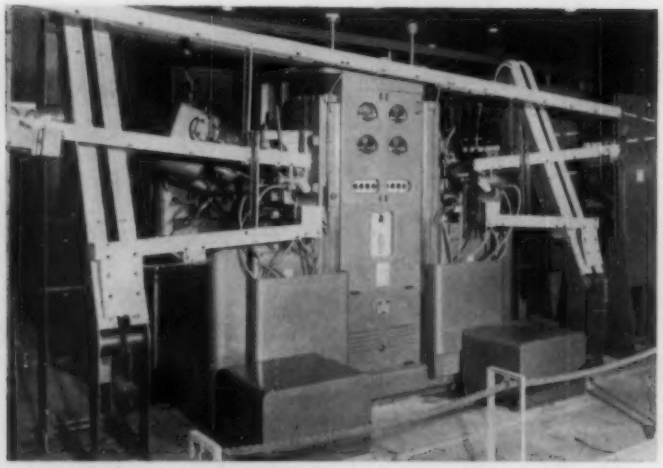
As usual, meatiest exhibits were provided by the East Germans. Emphasis was laid on the fact that in years to come the Fair will develop into an international center of machine-tool engineering, presumably as a counter to the European Machine-tool Exhibitions of the West. Accordingly, 118,000 sq ft of space is to be added to the machine-tool pavilion.

The "building block" theme recurred throughout East Germany's machine-tool, chemical plant, and control and measuring-equipment displays. They claimed 75% of their exhibited machine tools were automated, compared to only 25% in 1956. Moreover, an extensive program of standardization to cover all Communist countries in Europe is being readied, according to Prof Werner Winkler, deputy chairman of the top-level State Planning Commission.

Machine-tool exhibitors of East Germany listed 40 new constructions and 25 improved versions. Prominently featured were: a 14-station transfer line to machine electric-motor housings, with interchangeable tooling for four different sizes of castings; a high-accuracy abrasive cutter for semiconductor materials, reputed to be superior to contemporary US and UK machines because it is fully automatic; a copy lathe for machining armature shafts of electric motors, complete with an overhead traveling loader to pick the blanks off a storage conveyor and then dump the machine shaft onto an outgoing conveyor; a pair of transfer presses for stamping up to 500 truck wheels per hr; a six-station unit with eight horizontal and vertical spindle heads and fixtures that allow ends and sides of workpiece to be machined without repositioning.

Bulgaria partly fulfilled its promise of a year ago—to exhibit more machines, less apples. Fruit, handicraft and consumer goods were still in evidence at the Bulgarian pavilion, but there were lots of machines too. Rumanians concentrated, with successful audience effect, on huge oil rigs outside the pavilion and a big turbo-blower impeller inside.

Czechoslovakia's position as a major supplier of machine tools to the Soviet satellite countries now faces serious challenge from East Germany. Machine tools and allied equipment are almost 27% of the total industrial production of Czechoslovakia. By 1965

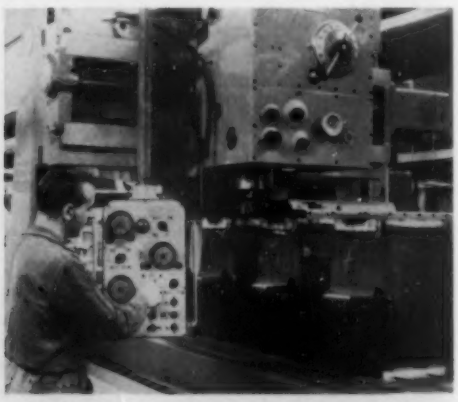


EAST GERMANY. Feature of gear-hobbing machine is its use for rough- and finish-generation of tooth systems. Machine control is electro-hydraulic and gear blank is held in a hydraulically actuated chuck. Hob feed is automatic and infinitely variable. Hobber, twin-spindle deburrer, washer and gear shaver are shown interconnected with storage hopper, gravity chutes and automatic loaders.

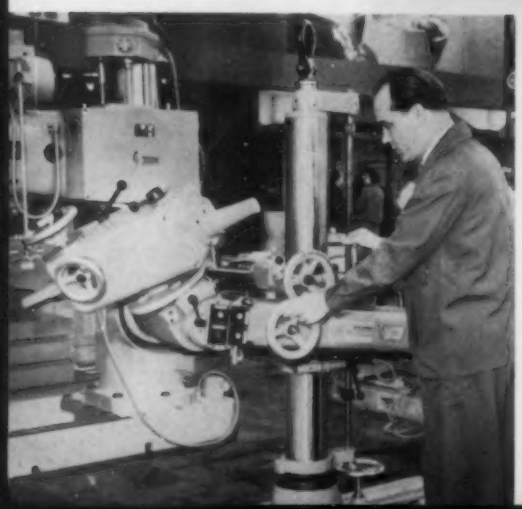
RED CHINA. Design simplicity and better controls were hallmarks of the 20 new machine tools exhibited by the Chinese. Multipurpose unit shown will machine six different sizes of engine blocks. Simultaneously, the machine mills several faces, bores and cuts threads. Average time to machine a single engine block is two minutes.

RUMANIA. Vast deposits of crude oil have led to development (right) of immense drilling rigs. Largest shown has a maximum drilling depth of 12,000 ft; smaller drills, 6500 ft. Equipment is up to date and includes torque converters plus power packs rated to 400 hp.

HUNGARY. (Below) This country's 11% increase in industrial production and 17% increase in foreign trade was reflected by 19 machine types it displayed. By far the most interesting was this portable radial drill. Unit can be moved on its four casters, or lifted easily by a 1½-ton crane. Main use is in the field.



CZECHOSLOVAKIA. As was expected, the Czechs showed some of the biggest machine tools and also precision instruments and equipment. Particular interest was concentrated on this perforated-tape-controlled milling machine, one of the few such units shown.,



BULGARIA. Major shift in emphasis was here, where agricultural products filled the exhibit space in past fairs. Machine tools dominated this year and, although nothing was startling new and many tools bore the unmistakeable stamp of Soviet design, there was little doubt that Bulgaria was industrializing its economy.

it should be 36%. Of all the machine tools exported throughout the world, 8.3% come from Czechoslovakia, which now occupies fifth position in the machine-tool export table–tops among the Soviet bloc of nations.

Contrasting with this (East-European exuberance, the Soviet pavilion, with part of its floor space left unused, was uninspiring. The Soviets called attention to agricultural machinery and a semiautomatic duplicating lathe for machining shafts with cylindrical and tapered bearing journals, which cuts machining time from 10 down to 4 min.

EAST GERMANS COULDN'T PAY

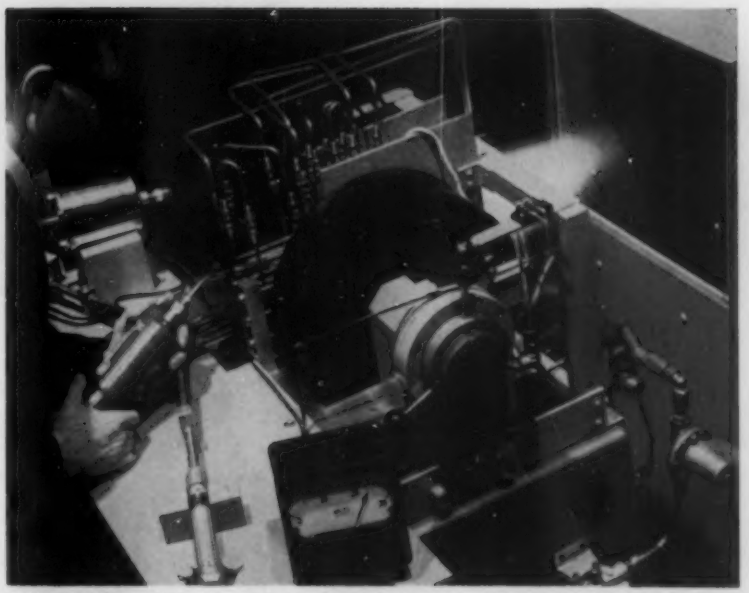
First US industrial organization to exhibit at Leipzig under the parent firm name since World War II was Morehouse-Cowles International Corp, Los Angeles, Calif. Norman Klein, manager of the exhibit, reported the sale of a 10-hp hydraulic variable-speed chemical and dyestuff mixer for $2500. He said he "sold" several other machines on display to East German state-owned firms, only to learn that cash payment was not available for the equipment.

Among Western exhibitors, West Germans and British were patently the most successful. Steel and machinery dominated West German activities, while for the British it was chemical-plant design and technology (a 40,000-ton ethylene installation) and electrical equipment for the aviation industry.

$1 BILLION IN SALES CLAIMED

East German hosts announced that 52 countries were represented at the Fair and that more than $1-billion worth of business was transacted, an increase of over 24% from last year. Western exhibitors injected a qualifying interpretation of the $1-billion figure, asserting that the bulk of the transactions were concluded prior to the Fair and that public announcement of the deals was held up to help fatten Fair totals. Nevertheless, the Fair was an obvious success.

Disconcerting to the West is the fact that representatives of the underdeveloped countries of Africa, Asia and South America–prime targets of the Communist economic offensive–seem to accept at face value the contention that Leipzig is the "trade center of the world." –Morrie Helitzer



MHD GENERATOR is designed for experiments with combustible fuels—fuel oil with oxygen at 5000 F. An MHD unit can propel a space ship or supply electrical power. For propulsion the energy-conversion process is reversed, changing electrical energy into the increased energy of motion of a plasma.

Four Novel Power Generators Are Put Through Paces

PITTSBURGH – Two reasons are cited for the increasing interest in new methods of power generation–fuel cells, thermoelectric generators, thermionic generators, and MHD (magnetohydrodynamic) generators. One is the growing concern about the diminishing supply of natural fuel sources; the other is the vital need for adequate power for man in space.

At the one-day symposium, Dr S. W. Herwald, research vice president for Westinghouse Electric Corp., said that "without these new methods man is helpless; with them, he can exist under almost any condition."

Other Westinghouse engineers and scientists cited the lack of suitable high-temperature materials as the major technical obstacle in the generation of large amounts of power by these methods. But for smaller power needs–space flight, military operation, and small remote power requirements –the practicability of these units is easily demonstrated.

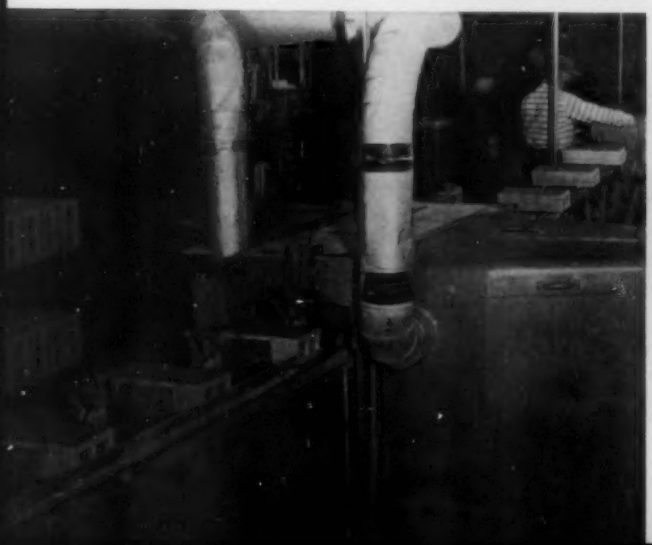
To prove the point Westinghouse showed and operated:

- A high-temperature experimental fuel cell, operating at temperatures above 1500 F, which converts a carbon fuel directly to electricity by electrochemical means.
- A 100-w thermoelectric generator that changes the heat of a gas flame directly into enough electric power to drive a bench grinder and a pair of auto headlights.
- A small thermionic generator capable of powering a small electric motor and two small light bulbs.
- An MHD generator producing 2½-kw at quarter power. This unit has been run for as long as 4 min. Previously reported units have had operating cycles of about 5 sec.

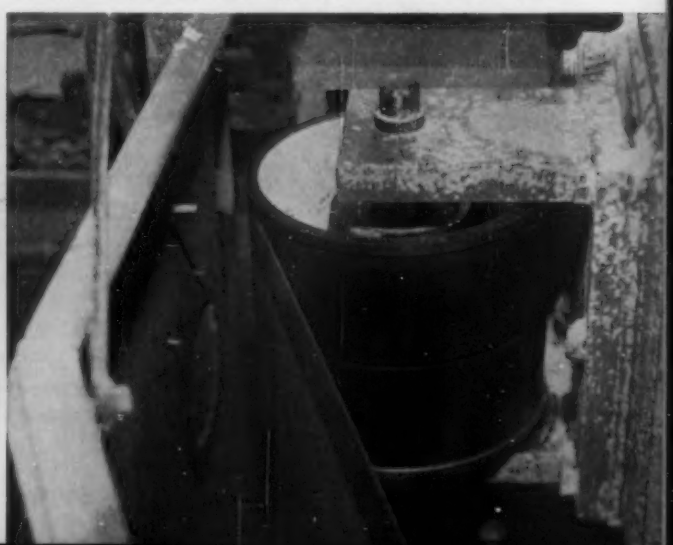
Dr J. A. Hutcheson, vice president engineering, of Westinghouse, said that company is nearing completion of a 5000-w thermoelectric generator "intended to be a small-scale prototype of a shipboard installation" for the Navy. A 1000-kw power plant is projected for the mid-1960s. He added that the fuel cell, thermoelectric generator and thermionic generator, because of small size, light weight, inherent long life, ruggedness and lack of moving parts, are "naturals" for space use. The MHD generator seems destined for large power uses. ■

Tile being ground to a tolerance of 1/16" in an overall length of 15¾". Two grinding heads staggered in same machine grind two ends in same pass. Due to planned oscillation, belt here is shown in lowest position of the cycle of the up and down movement on roll.

Tile production line showing automatic grinding machine equipped with LORIG-ALIGNER self-centering rolls to keep grinding belts perfectly aligned.



LORIG-ALIGNER self-centering rolls have a toeing-in action from both sides that keeps belt centered. Type 1 rolls were used on the sander.



Tile production boosted over 100% with belt grinders using LORIG-ALIGNER self-centering rolls

The Arketex Ceramic Corporation, Brazil, Indiana, produces load-bearing architectural tiles to within 1/16" tolerance to the 15¾" overall length. Both ends are ground or sized *before* glazing and firing.

Mr. Ralph Weston, Vice President in charge of production, says, "Originally the production line required hand grinding and delivered 5 to 10 tiles a minute. This was too slow. Next, we installed two emery wheels facing each other across the production line. Output went up to 11 tiles per minute but this was still not enough to satisfy us. In our search for higher efficiency, we called in the Ryman Engineering Company of Pittsburgh, a licensee for LORIG-ALIGNER rolls. They recommended installing two belt grinding machines so that both ends of the tile could be ground automatically at the same time."

In designing the belt grinding machine, Ryman Engineering used LORIG-ALIGNER self-centering rolls to keep the belts in perfect alignment. Production jumped, labor costs were reduced. The savings are obvious.

As a matter of fact, belt alignment was so perfect after installation of the LORIG-ALIGNER rolls that it was possible to install an oscillating feature. In this way, the full grinding face of the belt could be utilized. Arketex was so pleased with the efficiency of this machine that they later so equipped two additional lines. Similar grinding equipment is now under study for other products.

LORIG-ALIGNER self-centering rolls with their built-in centering action also have hundreds of applications in industry where conveyor belts are used or where continuous sheets of material must be kept in positive alignment. Steel or rubber-covered rolls are both designed to supply this action. These are obtainable from licensees for LORIG-ALIGNER self-centering rolls whose names will be supplied on request. For more information, send the coupon.

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United States Steel Corporation — Pittsburgh
Columbia-Geneva Steel — San Francisco
Tennessee Coal & Iron — Fairfield, Alabama
United States Steel Export Company

United States Steel

Mr. Ralph H. Weston, Vice President in charge of production at Arketex, compares rough, unfinished tile (top) with stack of accurately ground tiles.

United States Steel
Room 6064, 525 William Penn Place
Pittsburgh 30, Pa.

Please send your booklet, "LORIG-ALIGNER Self-Centering Rolls," to:

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AEC to Up R & D Spending During Next Ten Years

WASHINGTON—The Atomic Energy Commission—which already spends more for research and development than any other agency except the Defense Dept—expects to be spending even more over the next 10 years than the $600 million a year it is now.

This comes loud and clear from a new 300-page report from AEC, giving a rundown of its 20 laboratories with an explanation of why it expects to be hiring more than the 42,000 employes it now has, and which laboratories will expand what kind of work (see table).

Lately, there has been a running debate between AEC and some private organizations over the extent to which private industry could move in and do some of the work the laboratories now do. The Commission now says its labs should remain "paramount in pioneering work as the inventors and developers of new concepts and as the talented source of varied capabilities for tackling complex and unusual assignments."

The Commission admitted that expansion of some labs, such as Argonne and Oak Ridge, to more than 4000 to 5000 employes would reduce their effectiveness. But room for new projects and undertakings in the labs will be made by removing work which has reached the point where industry could carry on with it.

The report said, in effect, that for national defense purposes, Los Alamos Scientific Laboratory, the Lawrence Radiation Laboratory at Livermore and the Sandia Laboratory must be maintained as strong and vigorous institutions to research and develop essential weapons. The report was strongly endorsed by Senator Clinton P Anderson, chairman of the Joint Committee on Atomic Energy.

Copies of the report have been sent to industry with a request for comments on the following areas of the Commission's plans:

(1) Types of research which should be performed by national laboratories.

(2) Policies related to Commission labs' cooperation with industry and education institutions.

(3) Plans for future increases and decreases in effort at each of the Commission laboratories.

AEC's report is the latest sequence

Argonne National Laboratory, Lemont, Ill—Argonne does basic research in physics, chemistry, metallurgy, biology and medicine. It also has a major responsibility for applied research and development of power reactors. The lab will add to its present staff of 3600. Its budget for 1960 will be $42 million.

Brookhaven National Laboratory, Long Island, NY—This lab works on fundamental investigations of atomic nuclei. Equipment includes a large research reactor, a 3-billion-electron-volt synchrotron, a 60-ft cyclotron and several smaller accelerators. Scientists and engineers from other institutions come in for research and engineering in solid-state physics, biological effects of radiation, radioisotopes, and reactor fuels and components. In the next 5 years, a substantial expansion is expected. Employes now number 1800 and the budget for 1960 will be $20.5 million.

Oak Ridge National Laboratory, Oak Ridge, Tenn—The basic mission is to contribute to reactor development. The lab does R & D in metallurgy, chemistry and solid-state physics to improve reactor-fuel elements and construction materials. It conducts programs in chemical-process development for reactor fuels. Basic R & D programs are working on nuclear cross-sections, investigation of the interaction of radiations with matter and determination of the structure of crystals. These programs account for 75% of the 1960 budget of $56 million. The present staff of 5000 employes won't be increased during the next 10 years.

Ames Laboratory, Ames, Iowa—A modest total increase in research on the casting of uranium metals and its alloys is anticipated over the next 10 years. It has 400 workers and a budget of $3.8 million this year.

Lawrence Radiation Laboratory, Berkeley, Calif—This laboratory is engaged almost entirely in high-energy physics. Investigations on "subatomic" particles use accelerators and other elaborate bubble chambers. The present staff of 2300 and budget of $19.6 million will expand substantially.

Lawrence Radiation Laboratory, Livermore, Calif—Livermore studies controlled thermonuclear reactions, high-temperature reactors and peaceful uses of nuclear explosives (Project Plowshare). Work on Project Pluto, the nuclear missile, will increase and so will Plowshare. Present employes number 3600, 1960 budget is $24 million.

Los Alamos Scientific Laboratory, Los Alamos, NM—This lab is working on rocket propulsion for space explorations, materials, studies, constructions and operational test of prototype models under the Project Rover program. Budget for 1960 is $26 million; 4000 employes.

Aircraft Nuclear Propulsion Facility, Evandale, Ohio—Work on nuclear aircraft with General Electric as the prime contractor is performed here. Facilities include metallurgy, physics and chemical laboratories, critical reactor experiment cells and fabrication shops. Current efforts appear adequate for the next few years. Present total of employes is 2930 and spending for 1960 is $38 million.

Bettis Laboratory, Pittsburgh—Main work is on nuclear propulsion reactors for submarines. Personnel will be cut back to below 3000 from present 3600. 1960 budget is $53 million.

Aircraft Nuclear Propulsion Facility, Hartford, Conn—R & D is on work consisting of high-performance, liquid-metal-cooled, aircraft propulsion reactors. Pratt & Whitney is prime contractor. Work will expand from present total of 1600 employes and 1960 spending of $18 million.

Knolls Atomic Power Laboratory, Schenectady, NY—Has three major reactor projects: the submarine advanced-reactor project, the destroyer-reactor project, and a natural-circulation pressurized-water plant for submarine application. Staff will remain about 2200 and spending at $41 million.

Sandia Laboratory, Sandia, NM—Staff will remain at 2180. Sandia develops parts for atomic weapons.

Hannford Laboratory, Richland, Wash—Work has been undertaken to demonstrate the feasibility of utilizing plutonium as a power-reactor fuel. Spending in fiscal 1960 is $23 million with 1975 employes.

Savannah River Laboratory, Aiken, SC—Development work on natural-uranium-fueled, heavy-water-moderated power reactors will increase. Lab has 635 employes and spends $16 million.

In addition, AEC spends $23.2 million in five university labs: the Argonne Cancer Research Hospital at Chicago University; the Princeton and University of Pennsylvania Proton Accelerator Project (expected to cost nearly $12-million upon completion of construction); electron accelarator jointly proposed by Harvard and MIT; Princeton Model-C stellarator to determine feasibility of controlling thermonuclear reactions; University of Rochester Biomedical Project to determine safe exposure levels for various chemicals and radioactive substances.

in a debate initially triggered by the US Chamber of Commerce, the National Association of Manufacturers and the Manufacturing Chemists' Association. All three charged AEC with unfair competition in assigning to national labs research and development work that could be performed commercially. ■

Soviets Spur Automation of Machine Tools

Moscow—Soviet commitments to automation as a means of raising production is again manifest in a machine-tool program just announced by the program-control department of the Technological Designing Institute —a department of Leningrad's Economic Council. Under the program, turret lathes, lathes, milling machines and drills will be fitted with program control equipment.

V. G. Titov, an engineer associated with the projects, explains in a Leningrad newspaper that equipment such as turret lathes will be fitted with radioelectric command apparatus. He says that setting the machine and positioning tools for mass production will take about 20 min. Then the lathe can be left alone for 4 to 5 hours to carry out a fixed program.

Titov says the machine tool performs as many as seven different cutting operations. Machining that once took 15 min. will now take 2½ min. Production costs will be cut to about 17%.

DIFFICULTIES ARE ANTICIPATED

The program-control department has been instructed to supply Leningrad enterprises with 150 program-controlled lathes and turret lathes as part of the drive to increase worker productivity through automation. But according to the newspaper report, some difficulties are anticipated. The report says that only half of the 24 metal-cutting machines required to fulfill 1960 goals have been received.

Elsewhere, *Izvestia* reports that Leningrad machine builders are scheduled to produce "several" huge devices for machining rotors of large gas turbines The 120-ton machines, measuring 40 ft. long and 2 stories high, are expected to increase labor productivity on rotor machining by 2½ times. ■

German Engine Adopted into GE Gas Turbine Family

Lightest (about 100 lb) in a line of ultra-lightweight gas-turbine engines being offered by General Electric Company is this 75-hp powerplant, designed and built by Bavarian Motor Works (BMW), Germany. During GE's recent introduction of gas-turbine engines in the 50-through-20,000-hp class, it was learned that GE will have to buy its less-than-100-hp gas turbine from an outside source —in this case, BMW. The German engine has a fuel consumption of 66 lb/hr, and a lube consumption of 0.6 lb/hr. Speed of driven shaft is 3000 to 11,000 rpm. engine measures 2.3 ft wide, 2.4 ft long, 2.1 ft high.

Hertz Scholarships Go to Five Students

San Francisco—The Hertz Engineering Scholarship Foundation, set up in 1957 by Fanny and John Hertz as an outlet for the Hertz ("drive-it-yourself") fortune, has announced five 1960 scholarship winners. All from highschools in this area, the winners were selected on the basis of school records, test scores and financial need. They will pursue courses in mechanical and electrical engineering.

Foundation officers emphasize that the scholarship program is still in pilot stage. At present, they say, educators and industrialists are far from agreement on how to spot a potentially good engineer in highschool.

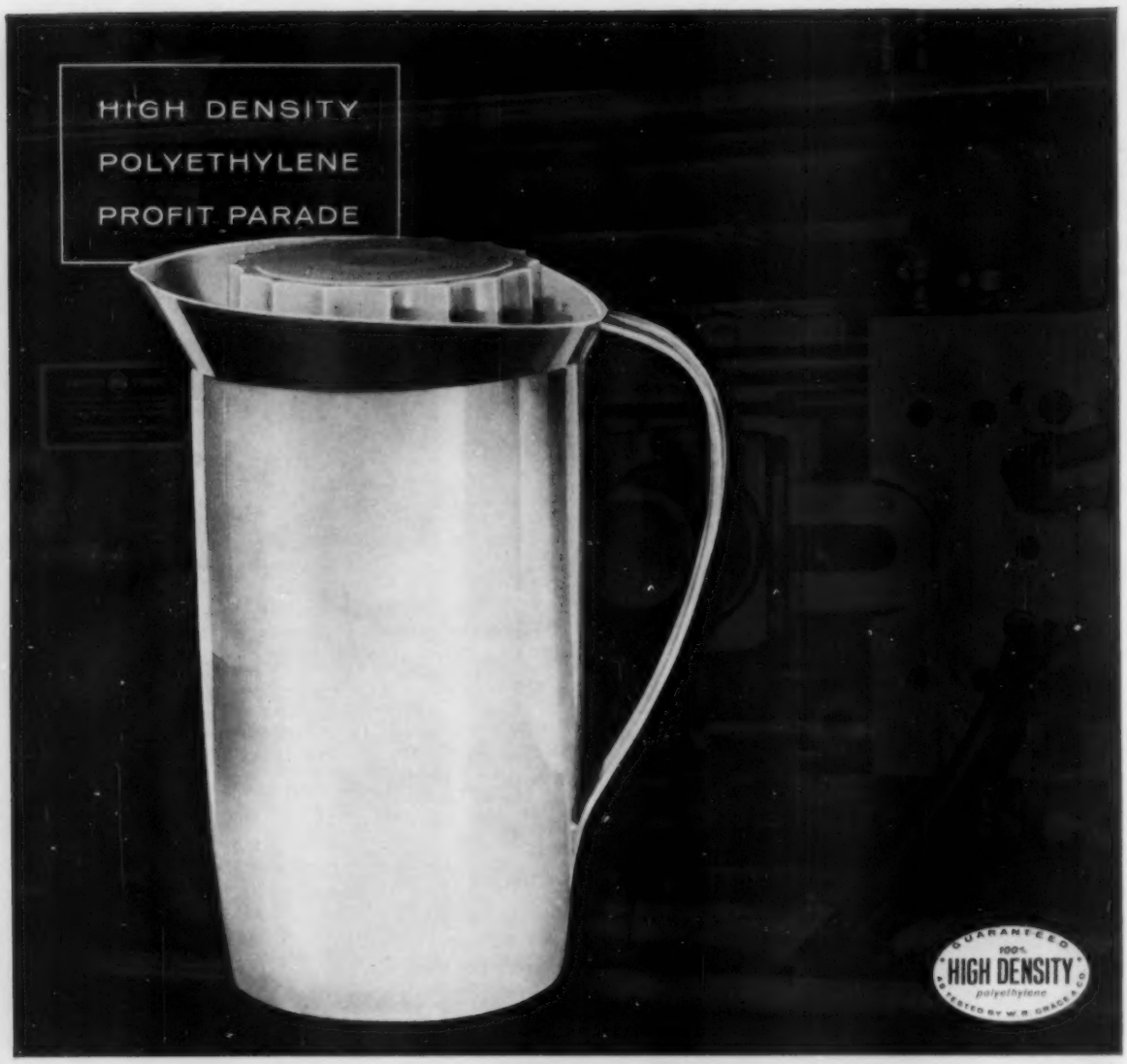
MECCA FOR ENGINEER SCHOLARSHIPS

Ultimately the Hertz Foundation may become one of the largest sources of private scholarships in the country —all earmarked for engineers. But it has not won wholehearted endorsement from all educators. Some universities have objected to certain scholarship provisions. The objectionable clauses include a pledge by winning scholars to volunteer their engineering skills to the government during national emergencies, and a required course in American history. ■

Japan Sets Up Research Foundation

Tokyo—A Science and Technology Promotion Foundation has been set up here by industry, the universities and other groups interested in research. Headed by Chikara Kurata, president of Hitachi Ltd, the foundation will recommend ways to promote science and technology to the government, and extend aid to research organizations.

One result expected is closer relations between industry and government and other public organizations; another is propagation of scientific and technical knowledge. Construction of headquarters for the foundation is expected to be complete by the end of 1962. State subsidies and private donations of $10.5 million have been accumulated for the construction and service program. ■



Grace Helps Expand a Housewares Line

If you have an idea for a new product that lends itself to high density polyethylene—but haven't done much more than preliminary thinking—now is the best time to call Grace in for help. Plastray Corporation can tell you this philosophy really pays off.

An established manufacturer of plastic housewares, Plastray wanted to expand its line with a new pitcher which they had designed and that would take full advantage of the profit-building properties of Grex high density polyethylene. Grace was brought into the picture from the beginning to help in the design and construction of Plastray's molds, and produce the first samples in the Clifton laboratories in time for the manufacturer to write orders at important trade conventions.

The finished product offers almost every feature that housewives look for in a pitcher. It is big enough to hold over two quarts, yet remains rigid and strong. It withstands the lowest refrigerator temperatures without losing its strength, and boiling water without losing its shape. Colors are permanently molded in. Chemicals often harmful to pitchers made of other materials cannot mar, stain or soften its attractive glossy finish.

Naturally, we are pleased to have played a major role in its development—and would like to help put your product in the Grex profit parade, too. Grace has the resin production facilities, technical service and experience you need. Everyone says we're easy to do business with.

Grex is the trademark for W. R. Grace & Co.'s Polyolefins.

W.R. GRACE & CO.
POLYMER CHEMICALS DIVISION
CLIFTON, NEW JERSEY

Pitcher reflects valid principles in designing for Grex.

Chances are you will never design a pitcher in high density polyethylene. Yet an understanding of the design characteristics of this particular pitcher may help you do a better job on applications for Grex in your own field.

Strength is needed. One of the major requirements for the pitcher centered on the fact that a full 70-ounce capacity was wanted. The need for strength and rigidity naturally followed. It is an interesting comment on the design itself and the physical properties of Grex that these requirements were met by generating a compound curve and using thin wall sections.

Use of thinner walls in any design for high density polyethylene results in production economies just as it did in this case. Fast molding cycles were achieved and material was saved. This is made possible by the outstanding physical properties of the material used. Variations in wall thickness and heavy sections were avoided in the pitcher design as a precaution against warpage, shrinkage and points of stress concentration.

Surface finish. A high gloss on the outer surface and pouring lip of the pitcher was desired for eye appeal. This was obtained by using a highly polished chrome-plated mold. The inner surface of the pitcher has a matte finish due to the fact that the mold's core is vapor honed to prevent sticking or freeze-up when ejecting the part. Practically any finish is possible in designing for Grex.

Call us for help. The pitcher story is a good example of the type of service we are ready and willing to provide you. If you are working on a design that calls for high density polyethylene —or are just in the thinking stage—now is the time to contact:

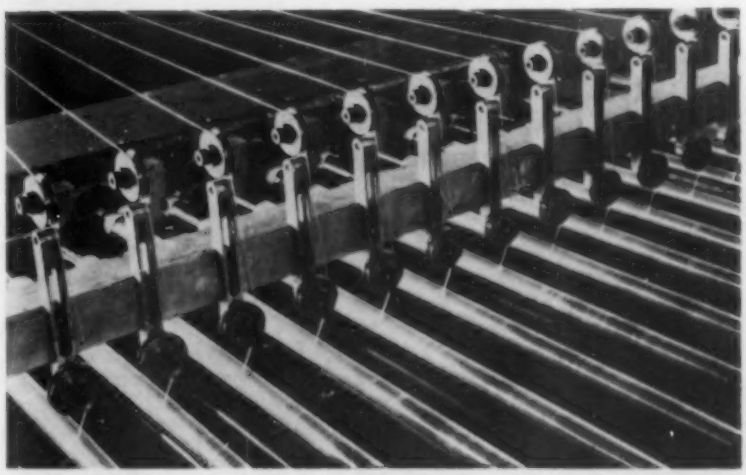
Technical Service Department
W. R. Grace & Co., Clifton, N. J.

THE ENGINEERING WEEK

Point-to-point Positioning of Machine Tools

Numerical-control equipment for machine tools, developed by Sperry Gyroscope Company of Canada Ltd, is applied for the first time in US to a variety of production machines. Here at Sperry plant in Great Neck, NY, equipment is used with a De Vlieg jigmill for the boring and milling operation of a part for missile guidance radar. System represents a unique combination of analog and digital techniques (*PE—May 25 '59, p 21*), incorporating highly accurate linear transducers, a tape reader that does not need a shift register or memory store, and a hydraulic valve that permits positioning accuracy at high travel speed. Sperry engineers report that the point-to-point positioning controls are accurate to ± 0.0005 in. and repeatability of ± 0.0001 in. They say that controls applied to one machine cost about $18,000 but can be amortized with a year.

First Fiberglass Gun Barrel



Some 500 miles of glass filament is wound around and fused to a tube of fine steel to form the barrel of the new Winchester Model 59 automatic shotgun. Cylindrical liner is made from seamless drawn-steel tubing with a wall thickness of 0.020 in. Thickness of epoxy-coated fiberglass wrap is varied to put strength where needed. The barrel is then oven-cured. Next, layers of fiberglass cloth are wrapped around the barrel, impregnated with resin, oven-cured and ground to finished contour. Barrel is then given a final spray finish of baking-type materials formed with epoxy resins. The holding lug and front sight are bonded directly to the glass resin surface with an epoxy-based adhesive.

POINTS OF VIEW

THE QUESTION: *When Should an*

Raymond Stevens
Former President
Chairman, Executive Committee
Arthur D Little Inc

More and more companies have sought the aid of the industrial consultant. But what should an engineering company look for in a consultant? When is the time to call in outside help? To learn more about consulting firms and what they offered the engineer, PRODUCT ENGINEERING asked Ray Stevens, outgoing president of Arthur D Little Inc, in an exclusive interview, to share his views and opinions with us.

Let us keep in mind that a consulting firm, like Arthur D Little Inc, first must know where a company wants to go, then help it get there.

"We've found that a company must first have internal strength. We've learned through experience that incompetence on the part of a client is a prime danger signal. Contrary to an opinion once held, a good consultant cannot long be supported by weak, small, incompetent clients. We cannot substitute for competence in management's upper echelon.

Remember, research is not a synonym for "magic". The client must realize that a lot of hard work, on both our part and his, must go into the project. And most important of all, there must be mutual trust so that both parties can work effectively. If a company is not willing to accept change, it is wasting its time by bringing in a consulting firm. Change is the basic element in any work we do, and any solution we may come up with will mean change of some magnitude to the client.

Not too many years ago, the American Oak Leather Co was making shoe soles. They were very successful at it. Soon, synthetics began appearing; but American Oak Leather had thousands of dollars tied up in tanning vats and leather-treating equipment. They couldn't see researching synthetics, with the risk of obsoleting all their existing equipment. Then along came neoprene shoe soles and the American Oak Leather Co was out of business.

We once had a client who had never faced the possibility that, when his patents ran out, competition would overwhelm him. He came to us in some anxiety because his market situation was rapidly changing for the worse, and he wanted to know what we could do to help him. A technical audit of his research activities indicated no real preparation for the day when his patent protection was gone.

Another problem we have encountered is lack of attention to the human side of product development. In too many product-design departments, people underestimate promotion. Research departments must be good at selling, and they have to start by selling their plan to top management. There has to be a little of the entrepreneur in every designer if he ever expects to capitalize on his product. Look at our great inventors; they were all top salesmen.

How to Choose a Consultant

What should a company look for in a consulting firm? Well, what should an individual look for in his personal doctor or lawyer? Loyalty and honesty, naturally. But he should also take a look at the clients they have served. How long have they been in existence, and what is their reputation in their community? Find out from some of their clients what kind of job they have done. When a doctor makes a mistake, it's buried. If an industrial consultant makes a mistake, it hurts him as much as the client, and a firm that makes mistakes won't be in business very long.

See what kind of people make up the consulting firm. At Arthur D Little Inc, we have to have men who like to work with people. This is especially true in the delicate initial discussion, when the problem is being focused. Not too long ago we held a staff conference on a troublesome situation resulting from a client's difficult personality and actions. During a heated part of the discussion an engineer on our staff pounded the table and said, "I am beginning to find that the trouble with engineering is that you have to deal with people." It is the trouble but also the joy of consulting.

Finding the Creative Man

We are also looking for the creative man. However, he is both hard to define and hard to find. We have found that we can't teach creativity. But we can encourage a man to be creative by not getting in his way. One of the weaknesses we've found in product-development depart-

Engineering Firm Seek the Aid of a Consultant?

ments is that they're so overorganized they stifle the creative thinker.

Some companies try to encourage creativity by calling top executives and engineers together for a brainstorm session. To me, brainstorming for this purpose is bunk. The responsibility for product planning must be assumed by staff officials, and they must assume this responsibility individually. Committees are fine as a means of communicating, but don't expect creative thinking from a committee. Creative thought must have a period of gestation. It can't come at 10 o'clock every Monday morning.

Too many companies will try to tailor people to an organizational chart rather than the chart to people. It's interesting to see how some of our older industries have been hurt by their over-organization and their reluctance to accept new ideas. They have become stagnant while some of our newer industries, like electronics and plastics, have rapidly advanced by constantly shifting their internal thinking. Notice the top management within these newer industries. They're all technically minded. And if they don't know the technology of their industry, they're in for trouble.

New-product Development

When a company has imaginative management, developing a new product is easy to envision. As I've said the most important ingredient in new-product planning is the basic philosophy of top management. Its attitude must be adaptable to change; there must be no built-in barriers. For example, a company's chief engineer may have had 40 years' experience in the manufacture of a steel product. Suppose a suggestion comes down from the men upstairs that the company is considering a switch to an aluminum or plastic product. The chief engineer's lack of enthusiasm to abandon steel in favor of the newer material might be enough to shelve the whole project.

A second provision in new-product planning is an appraisal to be sure the staff is properly organized to handle the change. There must be a sharp differential between line and staff organization. Line people, for example, must not judge a product's market. This responsibility must be handled by staff. Then staff, after making sure the company's finances can support the over-all project, must adopt a plan of action, and communicate this plan to the whole company.

During the preliminary planning, management may decide to call on a consulting firm as "management-staff counselors." One of the most important contributions a consultant can make is stimulation. Some years ago we studied the medical and scientific literature concerning the human skin, but nowhere in that study did we find a clear statement of where stimulation stops and irritation starts. The terms are synonymous; and whether a consultant stimulates or irritates, constructive action results.

In the development of the new product, the company also may want to call in an industrial designer to help with styling. Personally, I feel industrial designers do a good job. Theirs is a growing art, which is not yet fully developed. They try, for example, to do too much technical work for which they haven't been adequately trained. There is also a great need for the industrial designer to get closer to the people in research and development. This is not, however, a one-way street. Too many R & D departments insulate themselves from the industrial designer as well; closer understanding would benefit both groups.

Inventors and Patents

There is another resource that has been neglected by companies—the freelance inventor. Many good ideas have been junked by companies failing to give the inventor an honest appraisal. I don't mean to keep your door open to every idea salesman. When the National Inventors' Council began looking for freelance inventions, it found the few concrete suggestions buried by a lot of junk. An inventor has to have the same entrepreneur spirit that company's research department must have. However, he can't just bang on a door and expect to receive an audience with top management. He should get an introduction through a reputable institution or even a known individual. If he worked on his invention at a college or university, he should show the plans to one of the professors. This gives the inventor some backing when he approaches a company—a foot in the door.

If possible, the inventor should protect himself by obtaining a patent. Unfortunately, our courts have failed to interpret our present patent laws in the manner in which they were conceived. A patent was originally intended to give a man a limited monopoly on his invention. This is little enough to pay for progress, but today the courts too often have considered "monopoly" a dirty word. Actually, I'd like to see the original patent philosophy strengthened.

There have been many changes in the past few decades. Managements have changed, with a constant trend toward more professionalism, greater use of trained staff-specialist aids, deeper study of problems and better briefing for decisions. And one of the most striking developments has been the growth in use, acceptance, and understanding of research throughout our entire economy.

Ray Stevens has been with Arthur D Little Inc for 40 years. Early last month he became chairman of the executive committee, his post as president being filled by General James Gavin (*PE*—Sept 29 '58, p 21).

Mr Stevens was for years in the National Research Council. In 1955 he became Chairman of the advisory Board on Quartermaster Research and Development. He is a Fellow of the American Academy of Arts and Sciences, and has received the Gold Medal of the American Institute of Chemists for his contribution to research management. He is President of the Corporation of the Woods Hole Oceanographic Institution and 1957-58 Chairman of the Board of Trustees of the Gordon Research Conferences.—BAL

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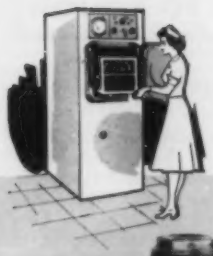
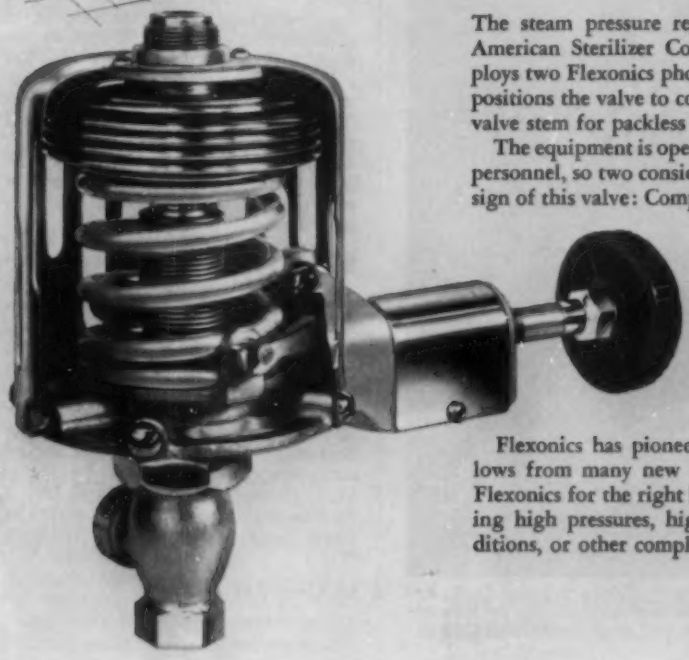


AMERICAN STERILIZER SELECTS **Flexonics** BELLOWS



The steam pressure regulator that governs the operation of American Sterilizer Company's surgical supply sterilizers employs two Flexonics phosphor bronze bellows in vital spots. One positions the valve to control steam pressure; the other seals the valve stem for packless construction.

The equipment is operated by nurses and other non-mechanical personnel, so two considerations outweighed all others in the design of this valve: Complete safety, with zero maintenance, practically forever. These demands had to be met in the face of such design problems as elevated pressure and temperature, possible corrosive conditions, and providing sufficient travel for close control over a wide turndown. After exhaustive tests, Flexonics bellows are now standard on all Amsco sterilizers and autoclaves.

Flexonics has pioneered the design and manufacture of bellows from many new materials including Hastelloy. Come to Flexonics for the right bellows design in any application involving high pressures, high temperatures, extreme corrosive conditions, or other complex problems.

Flexonics temperature sensor gives automatic top-burner cooking ... and slashes original cost

For use in either gas or electric ranges, this top burner control, designed and manufactured by Flexonics for one of the country's leading range manufacturers, allows them to offer automatic top-burner cooking at less than half the cost of previous devices used for this application. Installation costs, too, are greatly reduced. Temperature sensing head and fluid reservoir are one small, rigid assembly, connected by capillary tube to the Flexonics metallic diaphragm that operates the modulating gas valve or electric switch. Flexonics design and production abilities can be turned to your own needs—usually with the twin results of improved functioning and lowered costs.

Flexonics Bellows are the simple, straightforward answer to many touchy design problems. For pressure or temperature measurement . . . shaft sealing . . . even low-torque rotary motion . . . call on your Flexonics Bellows expert. Or write for the Flexonics Bellows Design Guide, 20 pages of useful information.

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DRAFTING TRENDS

Inspecting the "locked-in" black image of POST *208TC, Vapo Tracing Cloth, are Mort Fishman of Sabatino & Fishman, Architects, and Mike Ceglia of Bernard Sacks & Associates. Mike Conlin, sales representative of local* POST *dealer, Philadelphia Blueprint Company, looks on.*

Philadelphia engineers save hours per tracing

Remarkable reductions in drafting time, up to 40 hours per tracing, have been achieved by Bernard Sacks & Associates, Philadelphia engineering consultants.

Specializing in heating, plumbing, ventilating, electrical and structural work, this firm receives basic floor plans from architect clients, then makes up separate detailed plans for each construction trade involved.

Bernard Sacks & Associates employs a system using POST 208TC Vapo Tracing Cloth, a positive-to-positive diazo process material. It reproduces with a dense, "locked-in" black image. The original drawing is reproduced on this intermediate product, one for each subcontractor. In most instances, film positives of standard details can be overlaid on the original drawing before the intermediate is made, thus saving considerable drafting time.

Custom details or revisions are drawn directly on the 208TC intermediate, thanks to its excellent ink and pencil line receptivity. The finished plan is a combination of basic floor plan, transparent base overlays and additional drafting. It can be duplicated in quantity by any reproduction process.

POST Tracing Cloth intermediates, as in the above instance, are used in a wide variety of applications by many industries to help reduce costly board time. *For more information on* POST *208TC (black image) or 209TC (sepia image), and how they can help your company produce drawings and prints more economically, write to Frederick Post Company, 3642 Avondale Avenue, Chicago 18, Illinois.*

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READER TO EDITOR

Stop Gazing into Space

To the Editor:

I have been a subscriber to your excellent publication for quite a number of years and the temptation has often arisen to comment to the editor but for one reason or another I have refrained from doing so—that is until I read the recent article entitled—"What's it like on the moon?" (Feb 29, p 24) As I read this I came to the section wherein Dr Urey states "Secondly, there is the enormous thrill we can all get". This was followed up later on by "I have everything I want". At this point I became somewhat nauseated and I am confident that many of your good readers experienced the same awful feeling.

I have come to believe, as many others have, that it is about time that learned men like Dr Urey stop their gazing out into space and gaze carefully around them at the mess that we have in our own United States and in the rest of the world today. For everyone like Dr Urey who has everything he wants there are thousands who are overburdened with taxes, sickness and a host of other problems who are in no mood to be thrilled over someone taking off to the moon. Dr Urey better be well prepared to pay for this thrilling trip when he decides to go.

—ALFRED A REISER
Lake View, N Y

Dr Urey Replies

To the Editor:

In reply to Mr. Reiser's comments, I wish to say that I am sure many people in the United States are much less favorably situated than I am and it is understandable that my remarks may annoy them. But the difficulties of many people do not lie in the lack of wealth of the United States. The average per capita national product amounts to slightly less than $3000, of which the government takes about 20 per cent. I would gladly reduce taxes, but I see no way in the immediate future of decreasing our defense budget or even keeping it constant. Also, I believe we are lagging in our educational budget National defense and local education are the biggest items in taxes; saving on other items may be possibe but will not amount to much. Why not look elsewhere? Is eleven billion for advertising necessary? How about the tobacco or alcohol bills for which we paid 15.6 billion in 1958? Do we need 11.5 billion for new cars each year? Do we really wish to say that we cannot afford one or two billion for a really magnificent adventure in view of these extravagant expenditures? Each age and each people leaves a record of its great thoughts and enthusiasms—the beautiful Greek temples, the Middle Ages, the great cathedrals of Europe. Are we willing to leave only our automobile junk piles and soda bottles scattered at the roadside?

But distribution of wealth is always a problem. What is a just distribution and how is it to be attained? I am sure that

if we do not gaze at the moon and beyond and do not make our outlays for these purposes, no one in the United States will detect the difference in his living standards. In fact, the space program may make these standards higher. The stimulus to technical thought and invention will result from the enormous effort on the part of engineers and scientists that is necessary to accomplish these things. Possibly, miniaturization techniques learned in this way when applied to industry will pay the entire cost of the space effort and a tidy dividend besides.

It is possible that real scarcity and poverty face a small fraction of the United States population, but this is a separate problem, which is not solved by economizing drastically on one or another of our projects. If a person receives a low fraction of our national income it may be because of inferior ability, individual misfortune or an unjust distribution of income. Economy practiced in either the space program or the tobacco consumption will not per se correct any of these possible deficiencies.

—Dr Harold C Urey
Univ of Calif

Science vs Engineering

To the Editor:

Since the fall of 1957 when Sputnik I passed overhead and shattered US complacency, the cry has been "more scientists . . . we need more scientists." The panic alarm sounded, and the response has been widely apparent for some time—from Wall Street to the university.

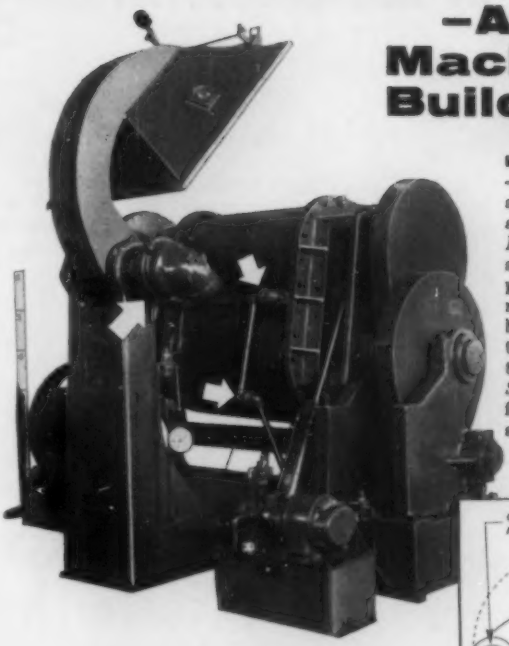
Without depreciating the value and importance of science, the value of engineering should be re-emphasized. A more earthly definition of engineering might include "making ideas work" as an essential feature. Any definition that excludes this part of engineering is certainly lacking.

Lately, it seems that this idea of making ideas work has been getting shoved out of engineering, especially at the academic level. Things that are too practical are often considered unworthy of attention by engineering professors; e.g., elasticity is much less distasteful than plain strength of materials. The rationalization is that practical things can be learned on the job.

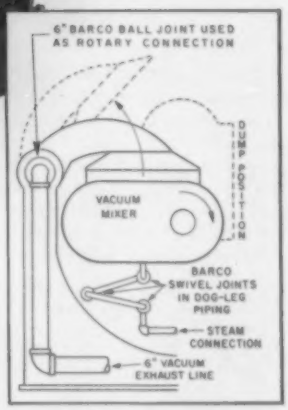
Certainly many practical aspects of engineering can be learned on the job, but a practical philosophy of approach and a practical concept had better be instilled at the grass roots level in an engineering college or it may never be learned. I'll bet a lot of elasticity students never learn much of the value of cut-and-try methods or of the use of such things as stress-coat . . . too practical and unscientific? (but maybe under a lot of circumstances, better). The Dresden atomic powerplant trouble (Jan 11, p 24) illustrates this point. The trouble was not science; it was engineering.

Besides the practical vs theoretical aspect of this problem, I'm worried about the effect the more abstract approach will have on engineering enrollments. In 1957, over one-third of the average engineering school's freshmen never became sophomores. Only about one-third of the entering freshmen will graduate in engineering. What will these statistics be in 1967? And

BARCO FLEXIBLE JOINTS —Aid Machine Builders!



BAKER PERKINS, INC. —On the big vacuum mixer shown at left (*also see sketch below*) a 6" *Barco Ball Joint* serves as a simple, dependable pivot point rotary vacuum connection to the movable hood of the tilting mixer trough. Below the mixer, three *Barco Self-Aligning Swivel Joints* are used to form a flexible "dog leg" steam piping connection.


6" BARCO BALL JOINT USED AS ROTARY CONNECTION
DUMP POSITION
VACUUM MIXER
BARCO SWIVEL JOINTS IN DOG-LEG PIPING
STEAM CONNECTION
6" VACUUM EXHAUST LINE

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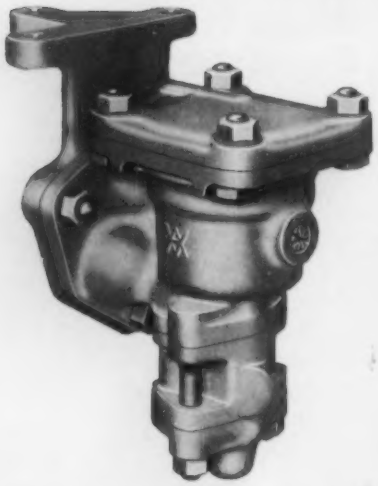
Typical Control Functions solved by AIR CIRCUITRY



● The H-5 RELAYAIR Valve, one of many Westinghouse Air Circuitry Components, is a pilot operated, directional control valve. It may be normally open or normally closed, depending upon port connections.

Various spring settings provide operating pressures from 3 to 150 psi. An easily removable pipe bracket permits removal of valve without disturbing pipe connections.

Envelope size: 7¼" x 7⅜" x 4⅜"
Maximum supply pressure 200 psi.

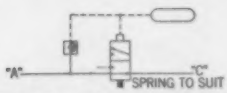
Typical Applications—In addition to the illustrated functions, this highly versatile valve has been and can be used in all conceivable types of air circuits. Some of these are as follows: cycling operations, safety interlocks, low pressure alarm signals, emergency cut-off of power, emergency brake applications, remote control station relays, sequence control timing, and many many others.

If you have a control problem, let us know about it. It can probably be solved with Air Circuitry. For more information, ask for Catalog A5-81.01.

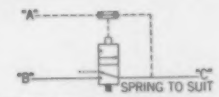
What is air circuitry?

This is the Westinghouse term for application of pneumatic control systems to industrial production operations. Safe, economical, precise Air Circuitry is now being used to solve the most rigorous and complex control problems in industry. Westinghouse Air Brake has pioneered the application and development of air control for more than 80 years. Today our engineers can design an air circuit which will help you boost production and cut costs in your plant or shop.

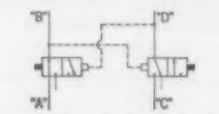
1. RELAY—To increase flow or pressure in an air circuit. An air signal directed to line "A" overcomes a spring opposed diaphragm to connect line "B" to line "C." Various spring values determine operating pressure.



2. TIME DELAY—To provide automatic power unloading. Air signal pressure in line "A" flows through the device to line "C" to perform specified operation. A check valve with choke and a volume provides a time delay by requiring a predetermined pressure be built up before line "C" is vented to atmosphere.



3. LOCK-UP—To provide a hold-in feature. Air signal in line "A" connects line "B" to line "C." Air from line "C," through a shuttle valve, holds this connection when signal air is vented.



4. CRISSCROSS INTERLOCK — To prevent energizing one line before another is vented. With lines "A" and "B" energized with air pressure, line "D" is vented to atmosphere. Line "D" cannot be energized until line "B" is vented. The converse is true when lines "C" and "D" are energized.

5. SEQUENCE INTERLOCK—To insure one function is performed before another is initiated. Line "A" must be energized to a predetermined pressure before line "B" can pass air to the next function.

See the Yellow Pages under Cylinders for the Name of Your Local Distributor

WESTINGHOUSE AIR BRAKE COMPANY
INDUSTRIAL PRODUCTS DIVISION, WILMERDING, PENNSYLVANIA

this in the face of dropping enrollments. (Feb 8, p 20).

It isn't so much a lack of ability as it is a lack of incentive and interest. A true engineer is not inspired by abstraction. He likes to keep his feet on the ground. I'm not advocating handbook engineering here —rather scientific engineering—but deadly practical.

As editor of a magazine whose engineering philosophy is reasonable, down to earth, and yet up to the minute, perhaps you will recognize this problem as being one of no small concern. I would certainly like to see it discussed in PRODUCT ENGINEERING, perhaps in a future editorial or even in a Points of View article.

—NAME WITHHELD

● See PRODUCT ENGINEERING's "Points of View", March 14, p. 24)—Ed

Daniel In the Lions' Den

To the Editor:

In surveying technical literature for articles, I came across your excellent editorial "Cold War Creep and Fatigue." (Dec 7 '59, p 61) You were angry when you wrote it, and I say in all sincerity "Thank God for that." It is stirring, and to me very rewarding to find that there are still men like yourself around, who speak, and write the truth, despite the trend to conforming lassitude.

While reading your editorial, an old verse from an almost forgotten hymn came to mind.

"Dare to be a Daniel
Dare to stand alone
Dare to have a purpose made
And dare to make it known."

What we need are more Daniels and fewer weak-kneed conformists. God gave each one of us a mind to develop, and to use, to separate wheat from chaff. We are expected to use this intelligence, each one of us, in a creative manner. That's why we are here. And let us not forget the words "He that hath eyes to see, let him see; He that hath ears to hear, let him hear." Your editorial has made an impression.

—DAVE EVANS
Pittsburgh, Penna

MUSES BY WHOSIS

In spite of fancy straps and flaps,
It's dear customer that loses
When the carton splits asunder
And the product fairly oozes.

If delivery he refuses
(With notation of the bruises)
He just winds up with a shipment
That he's sent on two more cruises.

You can always judge a vendor
By the packing style he chooses
To be battered by efficient
Transportational abuses.

If the packing is passed over
By a management that snoozes,
Insurance claims and bursting tests
Don't un-blow the buyers' fuses.

—D J ABRAHAM
Southborough, Mass

ADDENDUM

In the Feb 8 issue of PRODUCT ENGINEERING, (p 55) we listed societies and associations supplying information to the design engineer. Since publication, several omissions have been called to our attention. With apologies to those societies we missed, here is an addendum:

Institute of Environmental Sciences
PO Box 191; Mt Prospect, Ill
1000 members
No standards

Metal Etching and Fabricating Assn
1625 K St NW
Washington 6, D C
35 member groups
Standards to be published this year

Pressed Metal Institute
3673 Lee Rd
Cleveland 20
250 member groups
Suggested standards

Society of Technical Writers and Editors
PO Box 3706, Beechwold Station
Columbus 14, Ohio
No standards

COMING EVENTS

APRIL

4-8 . . . . Nuclear Congress and Exhibit, New York Coliseum, NYC.

5-8 . . . . Society of Automotive Engineers, National Aeronautic Meeting, Hotel Commodore, NYC.

6-8 . . . . Institute of Environmental Sciences, 1960 National Meeting, Biltmore Hotel, Los Angeles.

7-8 . . . . American Society of Mechanical Engineers, Management Engineering Conference, Statler-Hilton Hotel, NYC.

18-19 . . . . Joint Conference on Automatic Techniques, Sheraton Hotel, Cleveland.

19-21 . . . . American Society of Lubrication Engineers, Annual Meeting and Exhibit, Netherland-Hilton Hotel, Cincinnati.

20-22 . . . . Institute of Radio Engineers, 1960 Southwestern Conference and Electronics Show, Shamrock-Hilton Hotel, Houston.

21-28 . . . . American Society of Tool and Manufacturing Engineers, 1960 Engineering Conference and Exhibit, Detroit Artillery Armory, Sheraton and Statler Hotels, Detroit.

25-29 . . . . American Society of Mechanical Engineers, American Welding Society, Annual Meeting and Welding Exposition, Biltmore Hotel, Los Angeles.

26-27 . . . . Westinghouse Machine Tool Forum, Conrad Hilton Hotel, Pittsburgh.

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NON-FREE CYANIDE HARD BRIGHT GOLD

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Industrial 24Kt Gold

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STuart 1-6100
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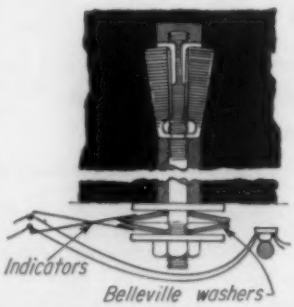
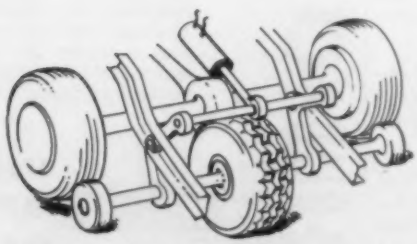
Chicago Office 7001 No. Clark

WHY DON'T THEY R&D..?

. . . some improvements in clinical measuring instruments for hospitals. It now takes more than five minutes—three times a day—to take a patient's pulse and measure his temperature. With modern instrumentation it shouldn't be necessary to heat a column of mercury to find whether a patient has a temperature—or to count heartbeats with one eye on a wristwatch to measure pulse rate. It should be possible to make a combined instrument with thermocouple (or thermistor) and electronic timer that would make the necessary measurements in a fraction of the time now required. The instrument should be inexpensive, self-contained, and small enough to be carried in the pocket. —J W SULLY

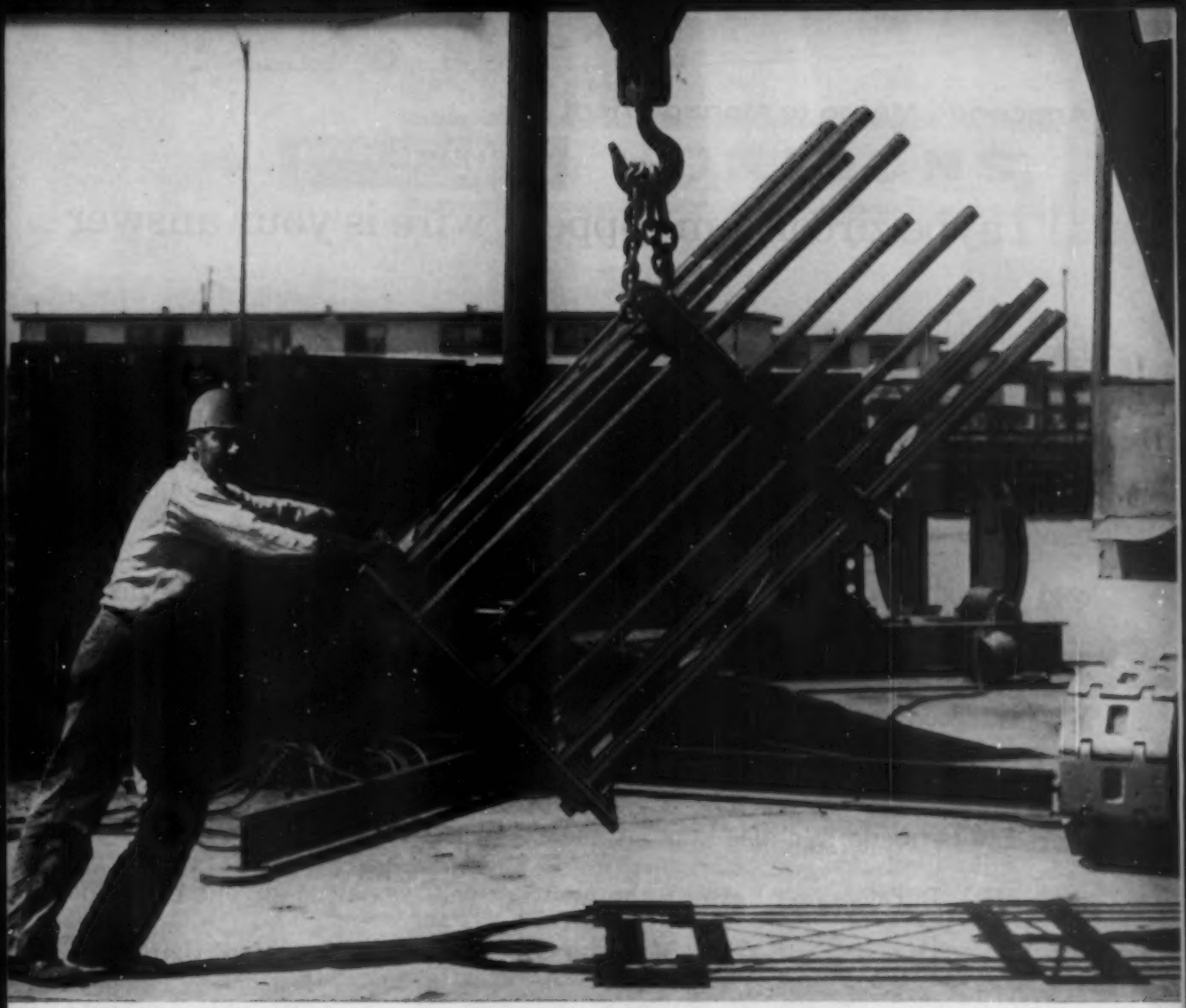


. . . bolts that indicate stress while they are supporting the roof of a mine tunnel. In the past 10 years, the method to avoid cave-in has changed. It used to be props acting against roof beams; now it's bolts mounted in holes drilled into the overhead rock. These bolts, 1 in. dia, 6 ft long, and about 5 to 6 feet apart, support the roof by clamping it against the firmer rock above the roof surface. They are cheaper than timber shoring, stronger, and do not interfere with movement of equipment through the tunnel. After they are installed, however, there is possibility that overhead rock will shift, and create a hazard. This condition was previously indicated by bowing of roof props; but over-stressed bolts give no warning. With an inexpensive indicator on each bolt, visible from 20 to 50 feet, hazardous roof conditions could be caught before cave-in. The market is potentially a large one—over four million roof bolts are installed each month in coal, metal and non-metallic mines in the US. One possibility for a stress-indicating bolt is shown in the sketch above. —S P JOHNSON



. . . a retractable wheel for automobiles and emergency vehicles, which is brought down on the road to supply maximum traction when rear wheels are stuck in mud, sand, snow or ice. With this wheel, tread design would not have to be the compromise needed to avoid noise, wear, or rough ride when snow tires or chains are used on streets and highways. The retractable wheel could be driven from rear wheels; lowering its driving axle into position would bring friction wheels in contact with the spinning rear tires. When lowered, it would also serve as a jack for the rear wheels. —J W SEYLAZ

Have you a problem, based on known scientific principles, which seems to have an answer somewhere within the limits of present technology? To inspire inventors along worthwhile paths, PRODUCT ENGINEERING invites you to trade such problems with fellow readers who have a fresh viewpoint or more time to experiment. We pay $10 for each once accepted.



Big bolts for the Giants' ball park

Threaded foundation bolts, two inches in diameter and eight feet long, 14 of them in all, were welded into this mammoth cage. This section will be embedded in concrete as an anchor for one of several steel shafts supporting the lighting system for the San Francisco Giants' new Candlestick Stadium.

The range of Bethlehem standard fasteners is wide enough to handle most bolting requirements. But quite often a special job, such as this one, calls for a special fastener designed to meet the specific need.

We can make an almost unlimited variety of special fasteners. Just send us a pencil sketch or drawing. Our fastener engineers will study it; and perhaps they can recommend changes that will save you money. We're equipped to give you prompt action. For full details, get in touch with our nearest sales office.

Candlestick Stadium, the new home of the San Francisco Giants

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Anaconda Memo to Management

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Looks like ordinary wire, but it's new and rather special. Amzirc®—zirconium copper, Cu 99.88%, Zr .12%—combines high electrical conductivity (90 to 95% IACS at room temperature) and strength retention at elevated temperature in the aged condition. Tensile strength of zirconium copper cold worked 80% and aged is about 70,000 psi at 20 C—52,000 psi at 400 C in a short-time test. Naturally, it has attracted interest in the missile field. We just recently finished drawing a batch of .0179" wire for testing as a conductor in some missile components, and now know that even smaller diameters can be made. We also know it has excellent hot- and cold-working characteristics. But we don't have all the answers yet—nor does anyone else. The reason we call it to your attention is that you may have a problem that won't wait until we can it as a completely proven product. Possibly we could work together in finding the answer. Our Metallurgical Department and mills are working with many copper alloys offering a variety of unusual property combinations. The answer might be Amzirc—or *Cunisil-837*, our copper-nickel-silicon alloy—or *Chromium Copper-999*—or *Leaded Nickel Copper-831*. All have a potential for special electrical applications.

If you are looking for metals to do new jobs—or to do present jobs better—tell us the combinations of properties you need. Call in your American Brass Company representative or write: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

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PRODUCT ENGINEERING HORIZONS

April 4, 1960

Packaged Minds

Less than half a century ago, butter came from a tub, crackers from a barrel, and beer from a keg—the only "packaged" products were eggs and nuts. But somebody discovered the convenience and saleability of attractive packaging, and we were on our skyrocketing way to the era of the supermarket. Now everything comes in bite, squirt or economy containers; we have conferences, congresses, and exhibitions on packaging; we even have packaging engineers and consultants, because in some fields the package has become more important than the product. This is not only true of foodstuffs and staples, but also of appliances, automobiles and some people.

In the latter case, the packaging is more than physical—it's mental, too. All their ideas and opinions come fully standardized, protected against change and neatly cartoned. Their children develop the same way. Education turns them out, wrapped in sheepskin, with concepts and sentiments carefully tied on and properly labeled. They're against sin and for motherhood, and the off-weight or off-color package is neatly and automatically discarded. As in other modern packaging, the cost goes up only a little, the carton is disposable (no refund) and the product is likely to be mediocre.

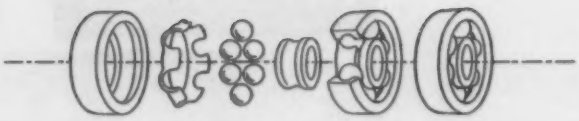
The same attitude inevitably spills over into industry in general and engineering in particular. There seems to be a "way" of doing things, an attractive package containing all the traditional approaches and allowances. There's even a packet of ready-mix frosting so you can "express your individuality."

There's only one catch—the resulting cake doesn't taste like the one Mother used to bake. It is vitamin-fortified, wheat-germ-enriched and artificially colored, but it has no originality and no taste.

What we're trying to say is that there's an increasing tendency toward conservatism and accepted approaches, toward faltering toddling when there should be some (at least) unregimented leaps. This is not the fault of engineers alone, but of the entire industrial and social structure, built on top of that packaged education mentioned earlier. We have carefully emphasized, all along, the things that can not be done, so all of us have turned timid.

After all, it *is* easier to keep things in their natural containers . . . they stack better and cause fewer headaches. But if the pattern is to be broken, if we are, as an industrial nation, going to try to take long developmental steps, Engineering must be the first to step out. That cannot be done without reversing the modern trend toward packaged minds.

R. Langeman



MEASURING ROUNDNESS OF INSTRUMENT BALL BEARINGS

By **RICHARD E. AMIDON**, *Staff Engineer, Production Engineering Department*
New Hampshire Ball Bearings, Inc.

Roundness of instrument ball bearings is a variable not covered by ABEC standards. Yet, it is an important factor in running quality. Since it is a very difficult variable to measure, except with costly equipment, most users must accept roundness on faith.

Roundness can be defined as "equidistance of all points on a curved surface from a fixed center". To measure roundness of a ball bearing component, therefore, you must establish its center and radius. However, since its center is not accessible as a point of reference, you must establish an "artificial" center. The closer the assumed or artificial center is to the actual center, the more accurate a given method of roundness measurement will be.

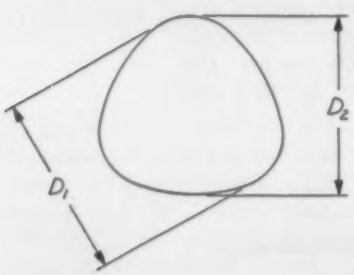
What you're really measuring is out-of-roundness, or deviation from a true circle. Such deviations are called lobing. There are three common ways of measuring out-of-roundness.

THE TWO-POINT METHOD

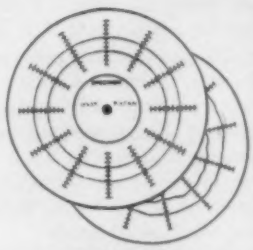
Most widely used of all measuring techniques is the method of measuring various diameters between two anvils as in a micrometer or two-point gage. The difference between the largest and smallest diameter is out-of-roundness. This method is accurate only if there is an even number of lobes of equal height and symmetrical spacing. Notice in the accompanying sketch of a three-lobed shape, all three diameters are equal . . . and the two-point method would indicate perfect roundness.

THE THREE-POINT METHOD

When an odd number of lobes exists, a three-point gage can be used to measure out-of-roundness. Variations are measured by rotating the part between two fixed points at a known angle with each other and a movable point connected to an indicator. This method, which calls for calculations to convert indicator readings to true-out-of-roundness, is accurate only when the number of lobes is known and they are symmetrically spaced and equal in height.



ELECTRONIC GAGING



POLAR CHART TRACE

Fortunately for you, instrumentation has been recently developed which measures out-of-roundness directly as radial variation with accuracy to several millionths of an inch. The part to be measured is chuck-mounted to a precision spindle and slowly rotated. An electronic gage head translates radial surface variations into a polar chart trace with deviations magnified as much as 10,000 times. Comparison of the chart trace with concentric circles of known radii reveals absolute deviation from a true circle. New Hampshire Ball Bearings, Inc. was the first to use this instrument as a quality control tool in the laboratory and on the production line. Other instrumentation used to assure the running quality of New Hampshire Bearings is described in our new Design and Purchasing Manual.

NEW DESIGN MANUAL

Newly revised and expanded, this authoritative publication covers everything you need to know about applying and buying miniature and instrument ball bearings. Comprehensive general information, catalog data and engineering bulletins are included in its 100-plus pages. Personally registered copies are available to qualified engineers, draftsmen and purchasing agents. Please send your request on your company letterhead.

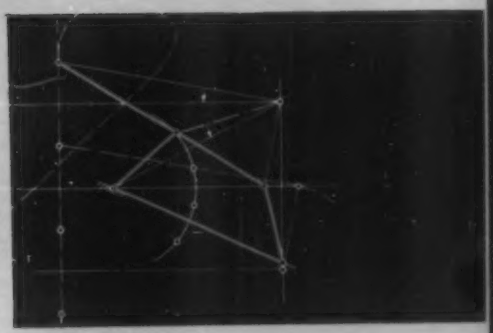
NEW HAMPSHIRE BALL BEARINGS, INC.
PETERBOROUGH, N. H.

PRODUCT ENGINEERING

SPECIAL REPORT

5 GRAPHICAL METHODS FOR

DESIGNING FOUR-BAR LINKAGES



This roundup covers the four-bar linkages that can generate a path approximating a straight line. The methods permit rapid solution of general configurations to fit space requirements, and they simplify mathematical solutions that find precise dimensions.

ERWIN P POLLITT, *advisory engineer, Continental Can Co, Chicago*

The classical problem here is to find a four-bar linkage that will generate a straight-line motion. Such linkages are used extensively in mechanical design, in place of cams and gears. Specific applications involve computers, instruments, counterweights and simple translators of rotary motion. Their preference over cams and gears depends upon analysis of their advantages and disadvantages. The advantages are simplicity, negligible friction (and wear), low inertia, economy, and stability in performance. The disadvantages are limited range, approximation of the desired motion, bulkiness, limited control over velocity and acceleration, and the fact that they are relatively difficult to design.

In general, linkages are designed by mathematical or graphical methods. In either case the characteristic problem is that of selecting from a large number of dimensional constants a particular set that will fit the specified space requirements and tolerances. The approach to the problem must be synthetic and approximate, instead of analytical and exact. The five graphical methods presented here offer a practical approach for determining the general configuration. Then, if necessary, mathematical methods can be applied to get the best out of the linkage with respect to the number of precision points and magnitude of deviation from the straight line.

Linkages developed by the five graphical methods have these characteristics:

Method A—These give a tracer point with nearly infinite radius of curvature.

Method B—Easiest to construct, but have a limited range characterized by two precision points.

Method C—Relatively harder to construct, but offer greater accuracy—up to five precision points.

Method D—These are the most accurate—up to six precision points. This is the limit because the equation of motion of a point is generally of the sixth order.

Method E—Offer four precision points, but can be adapted to more than four.

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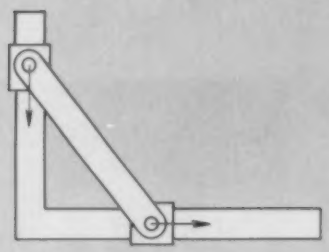
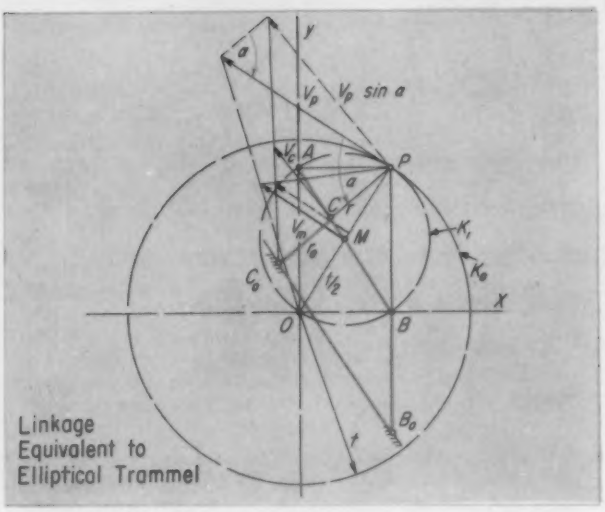


Method A

Synthesis of a Linkage Equivalent to Elliptical Trammel

Approach to solution: the component of the mechanism containing the point which performs the rectilinear motion is used as the coupler of the linkage; two points on this component are selected as the moving pivots, and the exact—or approximate—center of curvature of their path is made the fixed crank pivot.

The path of the tracer point of the linkage obtained has an infinite, or nearly infinite radius of curvature.



Linkage Equivalent to Elliptical Trammel

1

The bar is constrained at points A and B to move along the x and y-line. In the linkage the bar is made the coupler. Point B is made one moving pivot, and an arbitrarily chosen point C on the bar the second moving pivot. Crank BB_o, in the design position, is made perpendicular to the x-line, and as long as possible so that B moves approximately along this line while the center of curvature C_o of the point C on the trammel is selected as the second fixed pivot. Point A is then the tracer point.

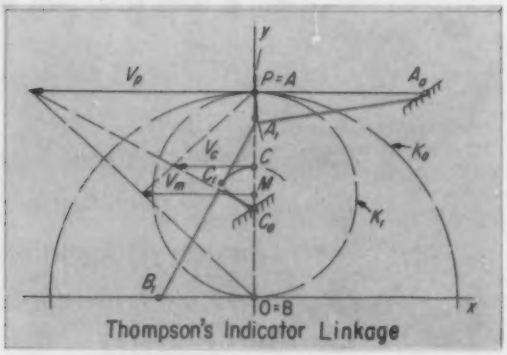
The center of curvature C_o of point C must lie on a line through C and the instantaneous center of rotation P of AB which is found as the intersection of the normals through A and B to y and x respectively.

The radius of curvature CC_o can be calculated, or solved graphically by the use of Euler-Savary's theorem in the form:

$$\frac{V_p \sin \alpha}{V_o} = \frac{r_o}{r_o - r}$$

where V_p is the velocity of the change of position of the instantaneous center, the angle between the tangent to the centrodes at the instantaneous center and the ray C_oP. V_o the velocity of point C of the moving system, $r = CP$, and $r_o = C_oP$.

The velocity of any point of the moving system, for instance, velocity V_m of the midpoint M of AB, is arbitrarily selected, and V_o determined. The fixed centrode of the trammel is the circle K_o with O, the intersection point of x and y, as center, and $OP = t$, the length of bar AB as radius; the moving centrode is the circle K_1 through P and O, with M, the midpoint of AB as center and $t/2$ as radius. The velocity V_p is determined from the consideration that the motion of the bar is equivalent to rolling of the moving centrode on the fixed centrode. V_p is therefore the velocity of this rolling motion, of the point of circle K_1 with which the instantaneous center coincides.

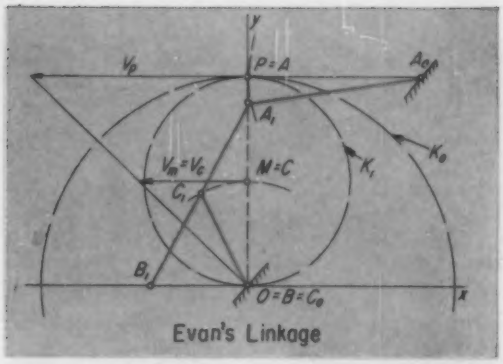


Thompson's Indicator Linkage

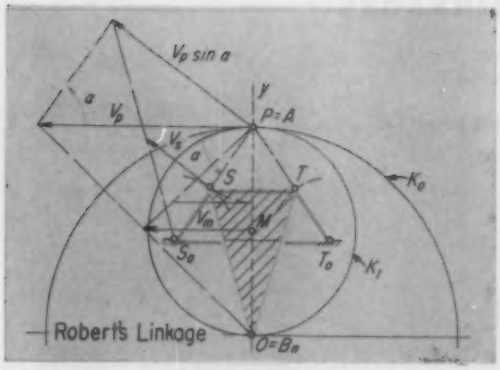
2

A special case of Fig 1 is the Thompson indicator mechanism shown here. It is widely used in radio sets for indicating the tuned frequency. To determine the linkage, the position of bar AB is chosen so that it coincides with the y-axis; then point A, which coincides with instantaneous center P, is made one moving pivot; and the fixed pivot A_o is located on the perpendicular to y through A. The center C_o of the curvature of the path of an arbitrarily selected moving pivot point C on line AB must also lie on the y-axis. Balance of the procedure is same as Fig. 1.

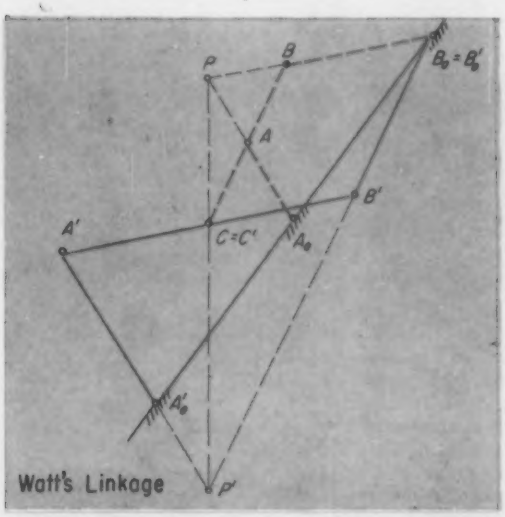
Having assumed the magnitude of vector V_m of center M of K_1 the vector $V_p \sin a$ can now be constructed. A line drawn through the end points of the vectors V_o and $V_p \sin a$ and the intersection of this line with CP determines point C_o.



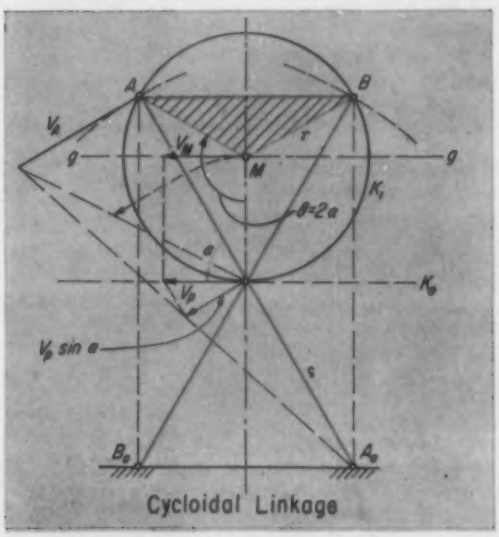
3
This is a second variation where point C coincides with center point M of bar AB; and C_o coincides with points O and B. Here, again, path of A approximates the y-axis, and path of B approximates the x-axis.



4
Here is a third variation of this group, with the moving crank centers symmetrical to AB, which again coincides with the y-axis.



5
By Robert's Law additional linkages can be found such that a point of their coupler performs a path identical to the path of a point of the coupler of a given linkage. In this linkage, A'_oA' and B'_oB' are so related to Evan's linkage that tracer point C' of the coupler of this linkage corresponds to the coinciding tracer point of C of the Evan's coupler. The fixed pivot, B'_o, coincides with B_o, and the fixed link $A'_oB'_o$ has the same direction as the fixed link A_oB_o of the Evan's linkage. Coupler $A'B'$ passes through C and is parallel to BB_o, while crank $B'B'_o$ is parallel to AB. Other similarities in the geometry are also apparent. This linkage is similar to Watt's linkage used extensively in steam engines.



6
Center M of circle K_1 rolling on a straight line K_o generates a straight-line motion along line g-g parallel to K_o. The contact point of the circle K_1 and line K_o is the instantaneous center P. K_o is the fixed centrode and K_1 the moving centrode. The motion of point M is approximated by a coupler link whose tracer point coincides with M, and whose moving pivots AB coincide in the shown position with two points on the periphery of the rolling circle which are symmetrical to the normal line to K_o through M. The centers of curvature, A_o, B_o, of the path of these two points are selected as the fixed pivots of the cranks, and they are determined as previously. The velocity V_p is equal to velocity V_m. The path of points A and B are cycloids whose radius of curvature may be calculated as follows: $\rho = 4r \sin \theta/2$; where r is radius of the rolling circle, and θ is its angle of rotation. The cycloidal linkage is used extensively in the textile industry.

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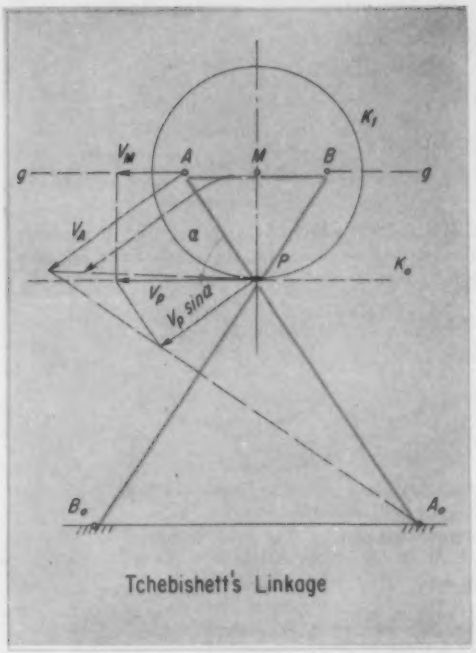
FOUR-BAR LINKAGES

Method A continued



Tchebishett's Linkage

7

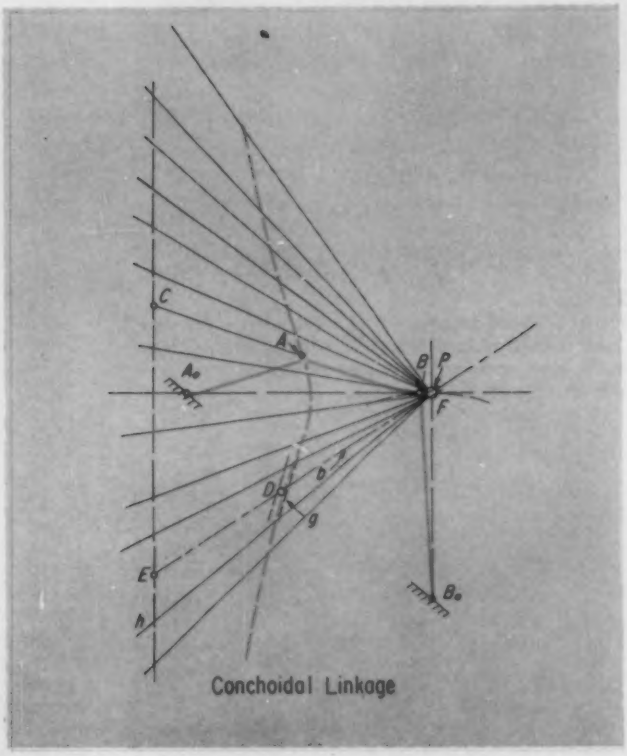
This is a modification of the previous linkage, with moving crank centers selected so as to coincide with two points inside the periphery located at equal distances from center of the rolling circle. One linkage of this type became known as Tchebisheff's linkage, characterized by a high degree of approximation to straight-line motion of the center point of its coupler.

EDITOR'S NOTE: For additional information on design of four-bar linkages see:

Robert's Law Helps You Find Alternate Four-bar Linkages, Oct 27 '58, p 54—Method of similar triangles is explained and expanded by author's approach—laying off the link lengths along a straight line.

Linkage Design Techniques, Dec '54, p 133—Gives comparison of 4 methods—two approximate and two exact—for construction and design of four-bar linkages.

Linkage Layouts by Mathematical Analysis, Aug '55, p 165—Shows how to obtain a specified relationship between input and output for a differential by determining number and types of links needed.

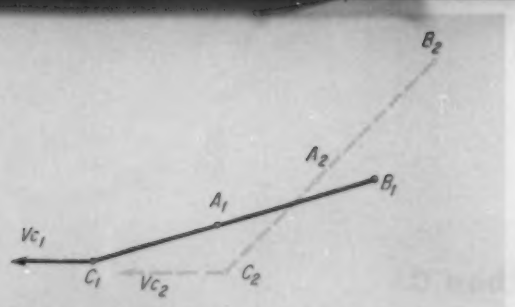


Conchoidal Linkage

8

The conchoid is the locus of points D on rays connecting all points of a generating straight line h with a focus F and having equal distance from the straight line. If the motion of a straight bar b is so constrained that the bar passes in all positions through the focus F (by means of a pivoted slide P); and point D, fixed on the bar, moves along a conchoidal groove g, another point, E, of the bar will describe the generating straight line h. Portions of this motion of point E are approximated by a linkage—A_oA, BB_o. A_o is the center of curvature of the conchoid at its apex, and A_oA is equal to its radius of curvature. AB is made equal to the distance between focus and apex of the conchoid, and crank BB_o is made as long as possible. Link AB is extended, and the distance between B and its end-point C is made equal to the distance between focus and generating line of the conchoid. Point C then describes an approximately straight-line path in the vicinity of the apex of the conchoid, and is used as tracer point.

To summarize characteristics of the above linkages, the path of the tracer point of the symmetrical linkages, Figs 4, 6 and 7, has an infinite radius of curvature. In the linkages of Figs 1, 2, 3 and 8, the corresponding radius of curvature approaches infinity as the length of the arbitrarily assumed crank is increased. In Fig 5 the tracer of the midpoint of the coupler will have an infinite radius of curvature when the linkage is in its antisymmetrical position, provided the cranks have equal lengths.

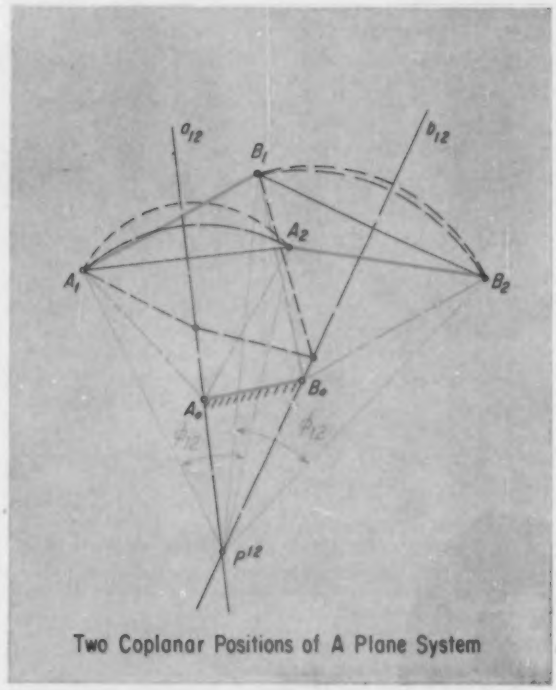


Method B

Synthesis of a Linkage Which Moves a Coupler Point Through Two Given Positions Such That Its Velocities in These Positions Are Collinear

Approach to solution: two positions of the moving crank, $A_1 B_1$, $A_2 B_2$ are arbitrarily selected; the locus of the instant center of those link configurations is constructed consistent with the velocity requirements and the selected coupler positions.

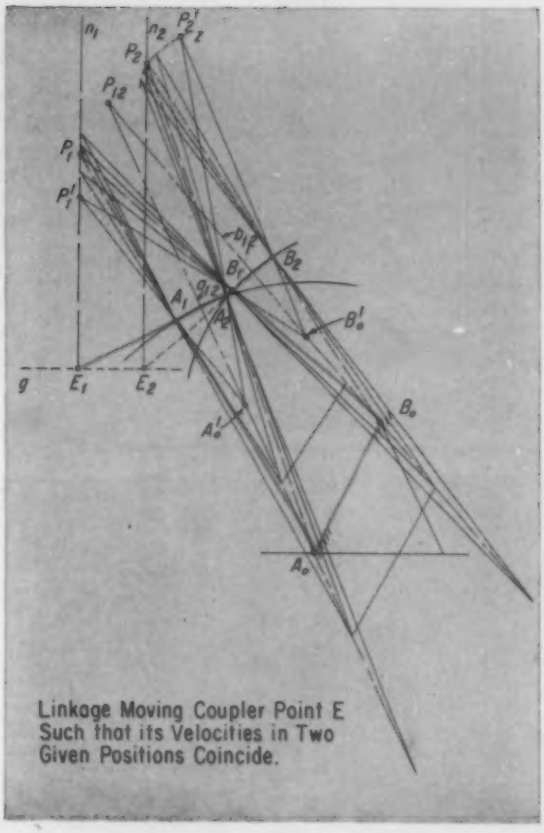
In the linkage obtained the path of the tracer point has two precision points and its tangents are collinear.



Two Coplanar Positions of A Plane System

1

This is a preliminary explanation of motion of the essential coupler link *AB* before showing the method of determining the required four-bar linkage in Fig 2. Here, a plane system *S*, containing coupler link *AB*, can be moved from position A_1B_1 to coplanar position A_2B_2 by rotation through angle ϕ_{12} about pole P^{12} which is determined as the intersection of the lines of symmetry, a_{12} and b_{12}, through distances A_1—A_2 and B_1—B_2, respectively. Pole P^{12} is a point common to the two positions of *AB* and the reference plane. This movement of *AB* can be accomplished by a four-bar linkage as follows: Connect coupler point *A* to any pivot point A_o on line a_{12}, and coupler point *B* to any point B_o on line b_{12}. A_oB_o is chosen so direction of the velocities of one point of coupler *AB* is collinear. Thus its path approaches a straight line.



Linkage Moving Coupler Point E Such that its Velocities in Two Given Positions Coincide.

2

Two positions A_1B_1, A_2B_2 of a coupler link *AB* are so selected that the positions E_1, E_2 of the third point *E* of the coupler lie on the straight line *g*, representing the approximate path which point *E* is required to travel. This line is direction of the velocities of *E* in its positions E_1, E_2. The instantaneous centers, relative to the reference plane, of the coupler in positions $A_1B_1E_1$, $A_2B_2E_2$ must lie on the normals n_1 and n_2 to *g* through E_1 and E_2. Also, the instantaneous centers must lie on the point of intersection of the lines A_oA_1, B_oB_1, and A_oA_2, B_oB_2, respectively, where A_o and B_o denote the yet unknown crank centers. Crank center A_o must also lie on the line of symmetry a_{12} of A_1A_2, crank center B_o, on the line of symmetry b_{12} of B_1B_2. If a point P'_1 on n_1 is assumed to be the instantaneous center for link position A_1B_1, the corresponding crank centers would be A'_o, B'_o, determined by the intersection of lines P'_1A_1 with a_{12} and P'_1B_1 with b_{12} respectively. The intersection point P'_2 of the lines A'_oA_2 and B'_oB_2 determines the corresponding instantaneous center of A_2B_2. P'_2 represents one point of the locus *z* of all possible instantaneous centers of system position $E_2A_2B_2$ for which the instantaneous center of system position $E_1A_1B_1$ lies on line n_1. The intersection point of this curve *z* with n_2 gives the instantaneous center P_2 of the link position $E_2A_2B_2$, which satisfies the requirement concerning direction of velocity of point E_2 and is used to construct the desired crank centers A_o, B_o. The path of point E_1 is nearly straight for a considerable distance past the positions E_1, E_2, so that the linkage is usable through a considerable range.

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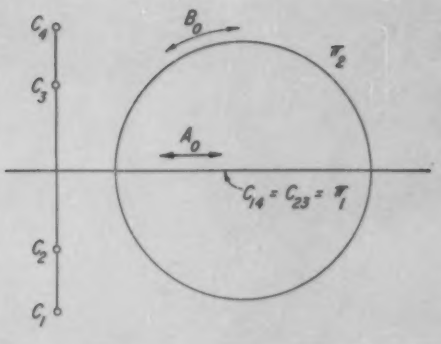
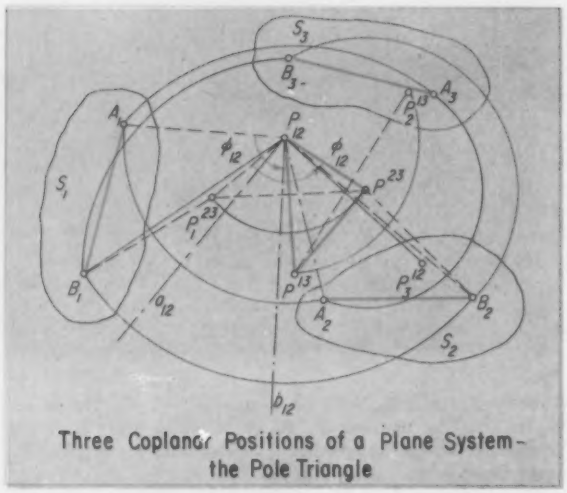


Method C

Synthesis of a Linkage by Means of Burmester's Focal Curves

Approach to solution (in its simplest form): two pairs of positions (C_1 C_4, C_2 C_3) of a coupler point, lying on a straight line and having a common bisector C_{14} are chosen; a degenerated curve of Burmester's centers is selected so as to coincide with this bisector; the crank pivots are found by determining the poles of rotation of the coupler.

In the linkage obtained, path of the tracer point has up to five precision points.



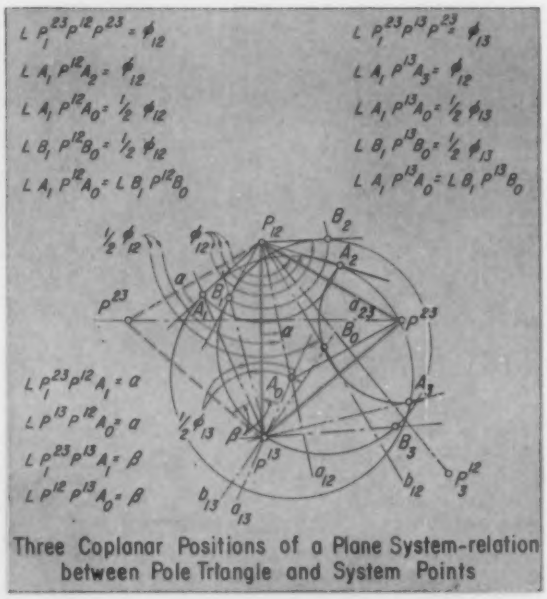
Three Coplanar Positions of a Plane System—the Pole Triangle

1

For an understanding of these methods it is first necessary to establish a certain relationship between congruent points of these coplanar positions of the plane system, their poles and angles of rotation.

For three coplanar positions S_1, S_2, S_3, there exist three poles of rotation P^{12}, P^{13}, P^{23}, forming the pole triangle which lies in the reference plane. The pairs of poles, P^{12} and P^{13}, are common to S_1S_2, S_1S_3 and the reference plane, respectively. Point P_1^{23} in the system S_1 is congruent to pole P^{23} and is found by rotating triangle $A_2B_2P^{23}$ about P^{12} until A_2B_2 coincides with A_1B_1. The angle of rotation from S_1 to S_2 is $P_1^{23}P^{12}P^{23}$, designated as ϕ_{12}.

Analogous relations apply to the points P_2^{13} congruent to P^{13} in system S_2, and P_3^{12} congruent to P^{12} in system S_3.

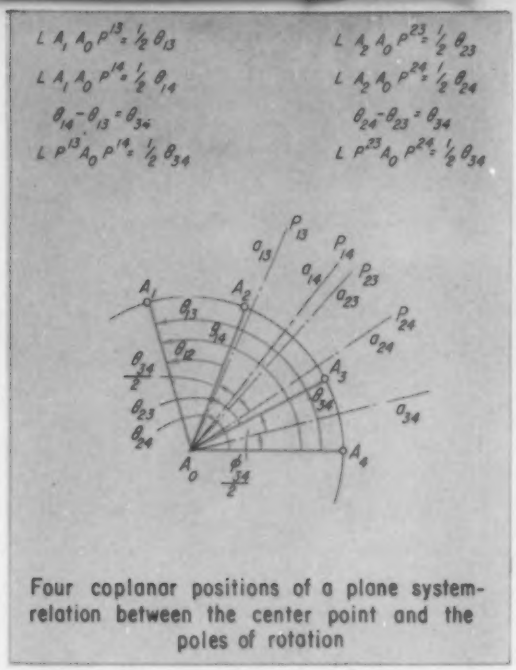


Three Coplanar Positions of a Plane System—relation between Pole Triangle and System Points

2

The three congruent points, A_1, A_2, A_3, lie on a circle whose center is A_0 at the intersection of lines of symmetry—a_{12}, a_{13}, and a_{23}. These lines of symmetry pass through their associated poles of rotation. Center point A_0 can be found without determining A_2 and A_3 from the noted angle relations. Angle $P_1^{23}P^{12}A_1$ must be equal to angle $P^{13}P^{12}A_0$, and angle $P_1^{23}P^{13}A_1$ must be equal to angle $P^{12}P^{13}A_0$.

Conversely the point A_1 associated with any point A_0 can be found by the same angle relationships. Corresponding angular relations exist between B_1, B_2, B_3, and Center B_0.

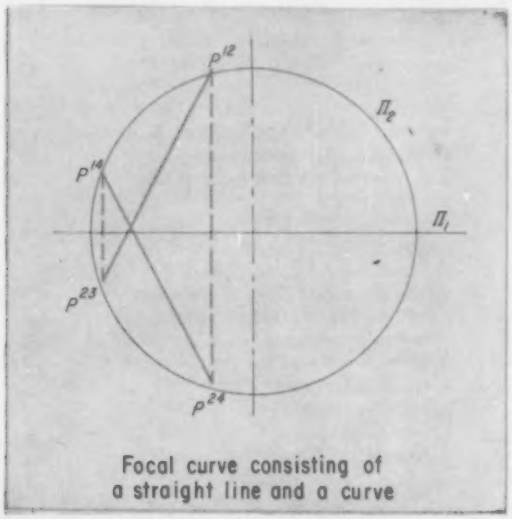


Four coplanar positions of a plane system-relation between the center point and the poles of rotation

3

To go one step further, if four coplanar positions S_1, S_2, S_3, S_4 of the moving system S are given, there exist six poles of rotation and twelve points in the system which are congruent to these poles. To determine the fixed pivots of a four-bar linkage capable of moving the system through these four system positions, two points in the moving system must be found whose congruent points in these four positions lie on a circle. Relationship between such points, A_1, A_2, A_3, A_4, and corresponding poles is shown. The center A_0 lies on the intersection of bisectors a_{12}, a_{34}, a_{23}, a_{24} of the angles $A_1A_0A_2$, $A_1A_0A_4$, $A_2A_0A_3$ and $A_2A_0A_4$. But poles P^{12}, P^{34}, P^{23} and P^{24} must also lie on these bisectors. From these angle relations it follows that the angles $P^{12}A_0P^{34} = P^{23}A_0P^{24}$, and $P^{12}A_0P^{23} = P^{14}A_0P^{24}$.

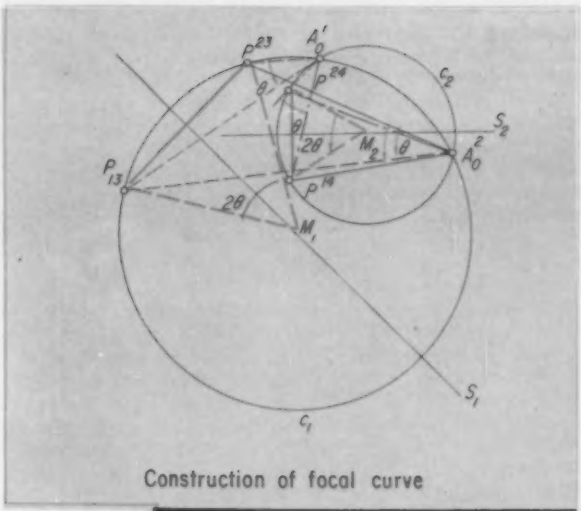
Thus, a point of reference plane at equal angles from any pair of poles with one common digit, is the center point of a circle called Burmester center—with four congruent points.



Focal curve consisting of a straight line and a curve

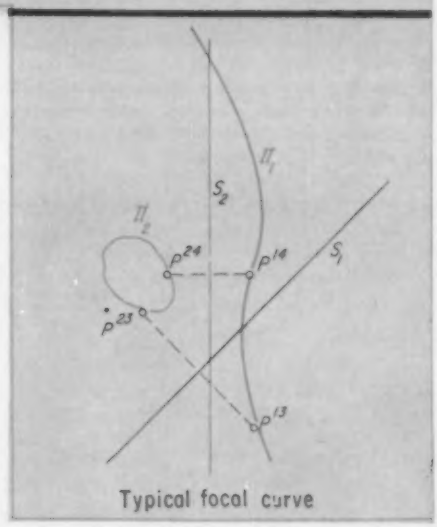
5

For certain pole positions the focal curve assumes very simple shapes. For example, if pairs of associated poles—P^{12}, P^{23}, P^{14}, P^{24}—are symmetrical to a straight line, the focal curve degenerates into straight line π_1 and circle π_2 through the four poles.



Construction of focal curve

(b)



Typical focal curve

(a)

4

The locus of all such points is a plane curve of the third order, called a Focal Curve, see (a), and the Focal Curve which is the locus of all centerpoints associated with four system positions is called the centerpoint curve. It can be shown that this curve passes through all six poles, and can be constructed by selecting two pair of poles whose indices have one common digit—for example, P^{12}—P^{23}, P^{14}—P^{24}—and drawing a circle through each pair of poles such that the radii of these circles are proportional to the distance between the poles of a pair; the points of intersection of the two circles, A^1_0, A^2_0, are points of the focal curve. The radius of the crank circle associated with each center point, and the location of the congruent points can be found by the angular relations illustrated in Fig 2, p 42.

When four system positions are selected in such a manner that four congruent positions of a point of the system lie on a straight line, and for these system positions the centerpoint curve is constructed, any two points on the curve can be selected as the centers of the cranks of the desired four-bar linkage.

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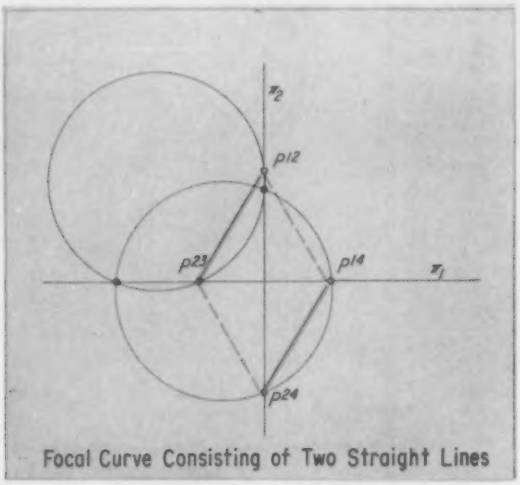
FOUR-BAR LINKAGES

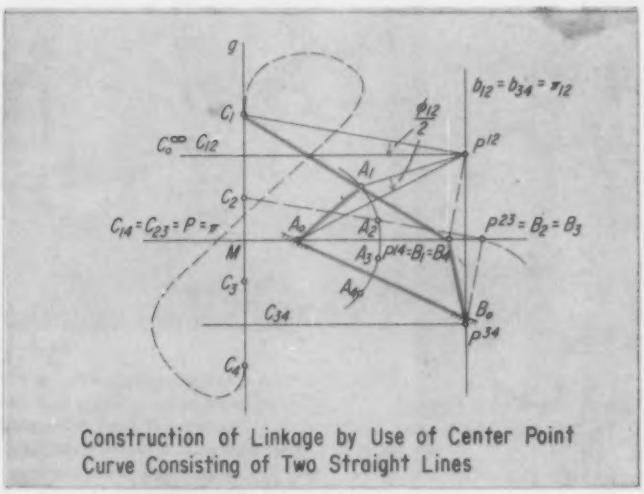
Method C continued



Focal Curve Consisting of Two Straight Lines

6

If the lines connecting associated poles constitute opposite sides of a rhombus, the focal curve degenerates into the diagonals π_1, π_2 of this rhombus and they are perpendicular to one another.

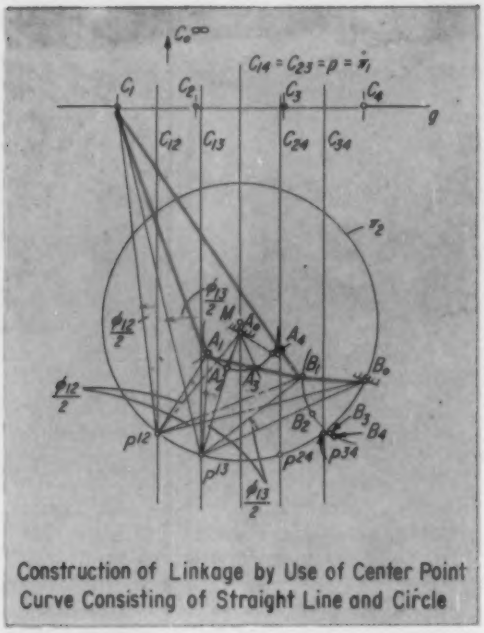


Construction of Linkage by Use of Center Point Curve Consisting of Two Straight Lines

8

This is another example of the use of the simplified shape of the centerpoint curve for the design of a linkage. As in the preceding example, four positions, C_1-C_4, C_2-C_3, on the line g of the coupler point C are selected so that they are symmetrical to the normal p Furthermore, the positions B_1B_4 and B_2B_3 of moving point B are selected so that they coincide, respectively with one another, and also lie on line p. In this case P^{14} coincides with B_1B_4, P^{23} coincides with B_2B_3.

The poles P^{12}, P^{34} must be the intersection points of line symmetry c_{12} of C_1C_2 and c_{34} of C_3C_4 with lines of symmetry b_{12}, b_{34} of B_1B_2, B_3B_4. By choosing this configuration, pole quadrangle becomes a rhombus; consequently centerpoint curve consists of the lines of symmetry p; centerpoint B_0 can be selected anywhere on b_{12}; centerpoint A_0, anywhere on p. Position A_1 of moving point A, which must lie on the line B_1C_1, can again be found by using angle relations of Fig 2, by making angle $A_1P^{12}A_0 = \frac{1}{2}\phi_{12}$. Conversely, movable pivot point A may be selected anywhere on the coupler, and centerpoint A_0 determined in an analogous manner.



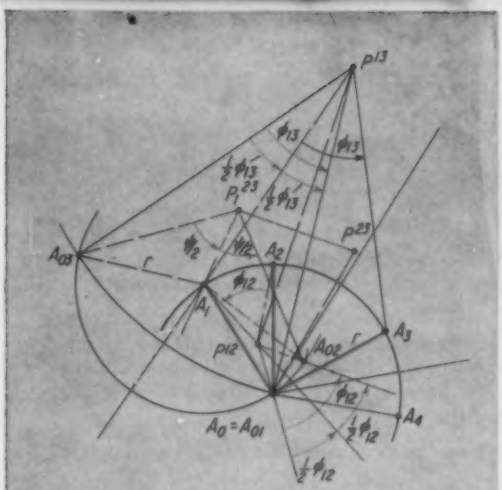
Construction of Linkage by Use of Center Point Curve Consisting of Straight Line and Circle

7

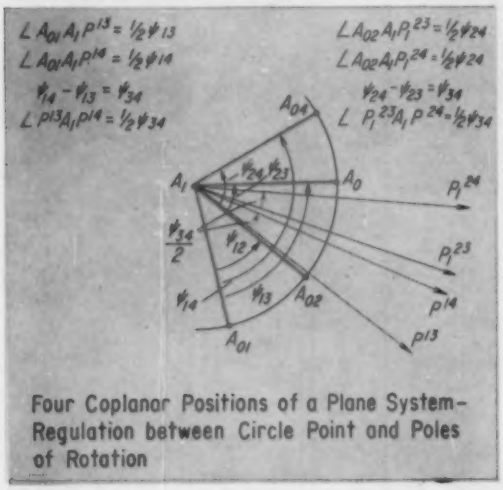
In designing a linkage by the use of the centerpoint curve it is convenient to select the system positions in such a manner that advantage is taken of the possible simplifications shown above. This is achieved here with four congruent points on a straight line chosen in such a way that C_1, C_4 and C_2, C_3 are symmetrical relative to the perpendiculars, p to g. Then the poles P^{12}, P^{12}, P^{34}, P^{34} must lie on the lines of symmetry, c_{12}, c_{12}, c_{34}, c_{34}, which are, respectfully, also symmetrical to p. Poles P^{12}, P^{12} are arbitrarily chosen on c_{12}, c_{12}, and poles P^{34}, P^{34} are placed symmetrical to them, relative to p on c_{34}, c_{34}, respectfully.

The centerpoint curve for this pole configuration is line π_1, coinciding with p, and the circle π_2, through the four poles. The crank center A_0 is selected anywhere on π_1. The position A_1 of the moving pivot A is determined by the angle relations noted on Fig 2, p 42, and Fig 3, p 43.

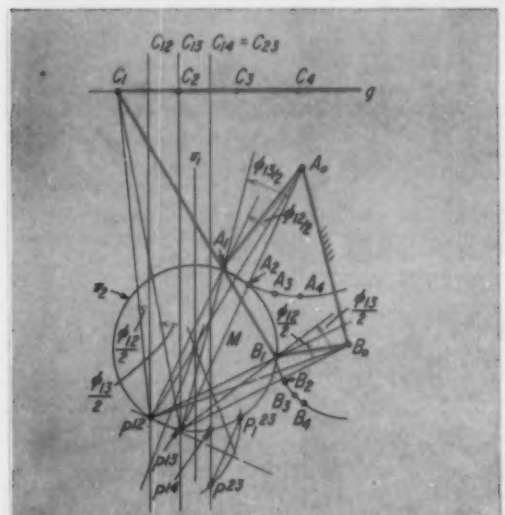
A ray through P^{12} is drawn, making the angle $C_1P^{12}C_2 = \frac{1}{2}\phi_{12}$ with line $P^{12}A_0$, and another ray is drawn through P^{12}, making the angle $C_1P^{12}C_3 = \frac{1}{2}\phi_{13}$ with line $P^{12}A_0$. The intersection point of these two rays determines the position A_1 of the moving pivot A and the length of crank A_1A_0. Crank center B_0 is selected anywhere on the circle π_2, and B_1 is determined by an analogous method as was used to determine A_1.



Relation Between Circle Point and Poles of Rotation



Four Coplanar Positions of a Plane System—Regulation between Circle Point and Poles of Rotation



Construction of Linkage by Use of Circle Point Curve Consisting of Straight Line and Circle

9

To each point of the centerpoint curve which lies in the reference plane and is the locus of all possible fixed pivots of cranks capable of moving the plane system through four prescribed coplanar positions, there is a corresponding moving pivot in the moving plane to which the crank must be attached. The relation between these points, called circle points, and the poles is illustrated here. This relation can also be used for designing linkages for generating approximately straight line motions.

Consider the systems S rotated back about the poles P^{12}, P^{13}, P^{14} to starting position S_1 from three positions, S_2, S_3, S_4. Then the points which in these system positions coincide with the center point will also rotate about the poles and since their distance from the movable pivot remains unchanged, they must also lie on a circle with the movable pivot, the circle point, as center.

This figure shows three congruent positions, A_1, A_2, A_3, of movable point A which lie on a circle with radius r, and A_{03}, the centerpoint, as center. Poles P^{12}, P^{13}, P^{23} are assumed to lie anywhere on the bisectors of the angles $A_1A_{03}A_2$, $A_1A_{03}A_3$, $A_2A_{03}A_3$. When system from position S_2 is rotated about P^{12} back into position, S_1 (held fixed in the reference plane), the point which in system position, S_2, coincides with A_{03} $(=A_{01})$ will go into position A_{02}, which is symmetrical to A_{03} relative to the line A_1P^{12}. When system from position S_3 is rotated back about pole P^{13}, so as also to come into coincidence with S_1, the point which in system S_3 coincided with A_{03} comes into position A_{04}, which is symmetrical to A_{03} with respect to the line A_1P^{13}. Both points, A_{02} and A_{04}, lie on a circle with A_1 as center and r as radius. Pole P^{23}, through rotation about P^{12} and P^{13} respectively, goes into its congruent position P_1^{23}. Since the distance of point P_1^{23} from the points, A_{02} and A_{04}, is equal to distance $P^{23}A_{03}$, the congruent point P_1^{23}, of pole P^{23}, must lie on the line of symmetry through the points $A_{02}A_{04}$, which also passes through A_1.

10

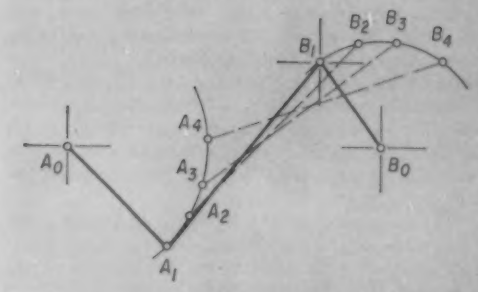
The locus of all circle points is also a focal curve which can be constructed in an analogous manner as the centerpoint curve, except that different pole points must be used as shown here. This relationship is analogous to Fig 3, illustrating the relationship of centerpoint to poles of rotation.

11

The circle point curve can also be used for designing a linkage for generating an approximately straight-line coupler motion. Again, by proper selection of the poles of rotation it is possible to obtain a degenerated form of the focal curve to simplify construction. Four positions of a moving system are chosen so that four congruent points of the system lie on a straight line, and their distances, C_1C_2, C_2C_3, and C_3C_4 are equal. In this case, pole P^{12} must lie on the line of symmetry c_{12} of C_1C_2; pole P^{13} on the line of symmetry c_{13} of C_1C_3 and passing through C_2, and both P^{14}, P^{23} on the line of symmetry $c_{14} = c_{23}$. For the circle point curve to degenerate into a circle and straight line (as in Fig. 5), P^{12}, P_1^{23} and P^{13}, P^{14}, respectively, must be symmetrical to a straight line. This line must be the line of symmetry π_1 of the lines c_{12},c_{14}, on which the poles P^{12}, P^{14}, respectively, lie. Therefore, P^{12} and P_1^{23} must also be symmetrical to line $P^{12}P^{13}$. If P^{12} is arbitrarily chosen on c_{12}, P_1^{23} is located symmetrical to P^{12} relative to line π_1. P^{23} is found on c_{23} by making the distance $P^{12}P^{23}$ equal to $P^{12}P_1^{23}$. Then P^{13} is determined as the point of intersection of the line of symmetry of $P^{23}P_1^{23}$ with line c_{13}, and P^{14} is the point on c_{14} which is symmetrical to p^{13} with respect to π_1. The line π_1 and the circle π_2 through $P^{12}P^{13}P^{14}P_1^{23}$ whose center, M, must also lie on π_1 are the two branches of the circle point curve of system position, $C_1A_1B_1$. The points A_1 and B_1 are chosen on π_2 so that they lie on a straight line passing through the tracer point C_1. The fixed crank centers A_0 and B_0 are found by considerations analogous to Fig 2, p 42. A ray is drawn through P^{12} which makes angle $\phi_{12}/2$ with A_1P^{12}. Another ray is drawn through P^{13} which makes angle $\phi_{13}/2$ with A_1P^{13}. Crank center A_0 is the point of intersection of these two rays. Crank center B_0 is determined in an analogous manner.

By proper selection of the positions of the poles of rotation, the circle point and centerpoint curves described above offer the simplest means for the application of Burmester's method to design of four-bar linkages.

continued, next page

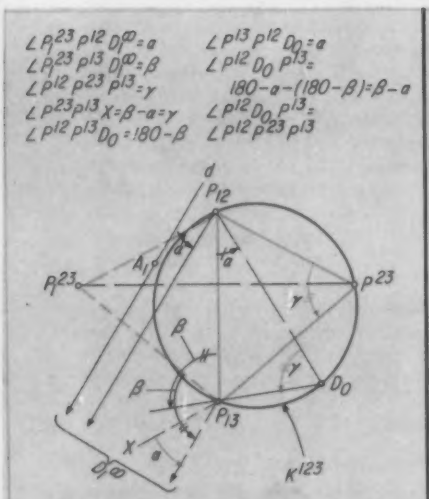


Method D

Burmester's Method for Determining, in a Given Linkage, a Coupler Point Which Performs an Approximately Straight-Line Motion

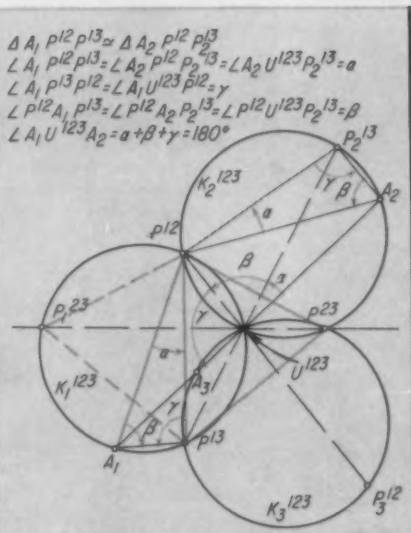
Approach to solution: four positions of a four-bar linkage ($A_1 B_1$—$A_4 B_4$) are chosen; the properties of the pole triangle and of the circle point curves of points at infinity of the coupler are used.

The path of the tracer point obtained has four precision points.



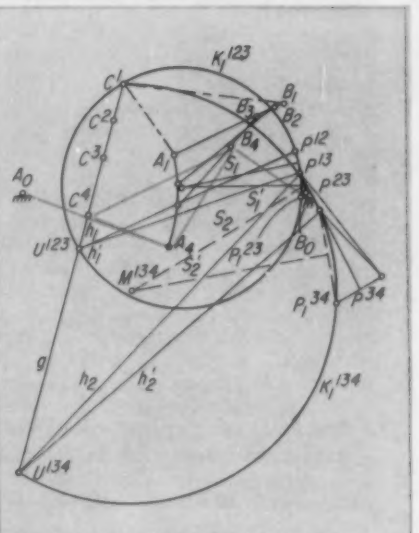
Three coplanar positions of a plane system—location of the center points of system points at infinity.

a



Three coplanar positions of a plane system—location of three congruent points, relative to the pole triangle, lying on a straight line.

b



Four coplanar positions of a plane system—location of four congruent points lying on a straight line.

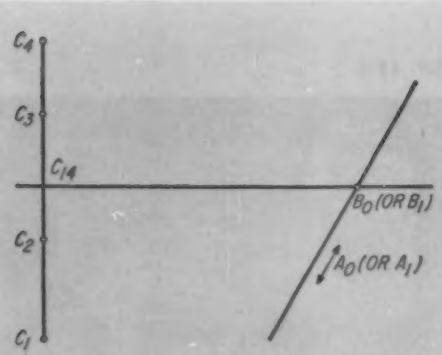
c

Since there are an infinite number of linkages capable of moving a system through four given positions in such a manner that four congruent points of the system lie on a straight line, it is possible to reverse the problem. That is, find a coupler point in a given linkage such that its four congruent positions line on a straight line. In the method developed by Burmester for solving this problem the angle relations of Fig 2, on p 42, are applied. The straight line is considered a circle with infinitely faraway center point.

If point A_1 in the system S_1—see (a) above—moves along a straight line d to infinity, then the rays $P^{12}D_1$, $P^{13}D_1$ through the infinitely faraway point D_1 at infinity become parallel. The center point D_∞ associated with D_1 is constructed as in Method C, Fig 2, p 42, by making angle $P_1^{\infty}P^{12}D_1 =$ angle $P^{12}P^{13}D_\infty$, and angle $P_1^{\infty}P^{13}D_1 =$ angle $P^{13}P^{12}D_\infty$. If this procedure is applied to all infinitely faraway points of system S_1, S_2, S_3, it is evident that all center points associated with the points at infinity of the moving system lie on the circle k^{123} through $P^{12}P^{13}P^{23}$ in the reference plane.

Conversely, by the previously established to the relationship between circle point and centerpoint, the circle points associated with the center points at infinity, of the reference plane, must lie on the circles —see (b) above—k_1^{123} through $P^{12}P^{13}P_1^{23}$ in system S_1; k_2^{123} through $P^{12}P^{23}P_2^{13}$ in system S_2; k_3^{123} through $P^{13}P^{23}P_3^{12}$ in system S_3. If three congruent points, $A_1A_2A_3$, of the system lie on these circles, their centerpoint must be at infinity and the three points must therefore lie on a straight line. If two of these circles k_1^{123}, k_2^{123}, their intersection point U^{123}, and the triangles $A_1P^{12}P^{13}$, $A_2P_2^{13}P^{12}$, are considered, it is noted that the sum of the angle $A_1U^{123}P^{12}$ and $A_2U^{123}P^{12}$ *is* 180°, and that the straight line A_1A_2 must pass through point U^{123}. From these geometric relations it must be concluded that three circles intersect at U^{123} and that a straight line carrying three concruent points A_1, A_2, A_3 must pass through this point.

Now if four coplanar positions—see (c) —of the systems S_1, S_2, S_3, S_4, are given, the pole triangles P^{12} P^{13} P_1^{23} and P^{14} P^{24} P_1^{34} for S_1 S_2 S_3, and S_1, S_3, S_4, are determined, together with their centers of height U^{123}, U^{134}. The line connecting these two centers of height is the only line which carries four congruent positions of a point of the system. The position point, C_1, of the tracer point of the coupler is determined as the intersection point of the line U^{123}, U^{134} with the circle k_1^{123}. Center M^{123} and circle k_1^{134} center M^{134}. The linkage with the coupler point at C_4 is shown at position S_4.

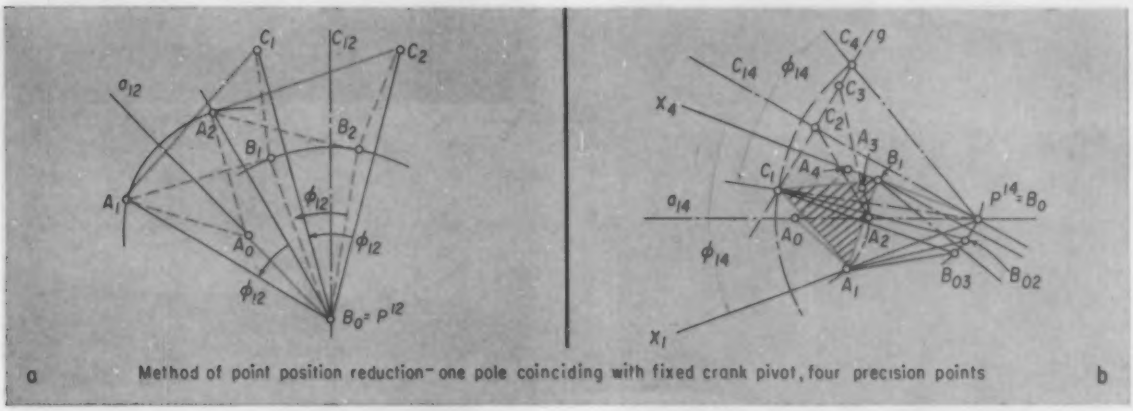


Method E

Synthesis of the Linkage by Point Position Reduction

Approach to solution (in the simplest form): four positions (C_1-C_4) of a coupler point lying on a straight line are chosen. The position of one fixed crank pivot B_0 or one position of pivot B_1 is selected on the bisector of two coupler point positions; the other pivots are determined by considering motion of selected pivot relative to coupler.

In the linkage obtained, the path of the tracer point has up to six precision points.



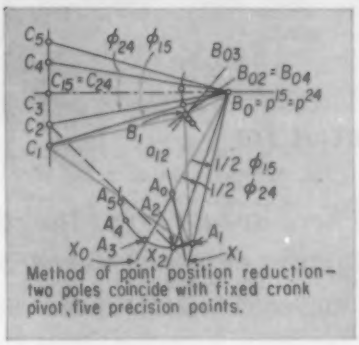
a — Method of point position reduction—one pole coinciding with fixed crank pivot, four precision points — b

1 This method, developed by Kurt Hain of the West German Federal Research Institute of Agriculture, is based on selecting the poles of rotation of the moving system in such a manner that one of them coincides with either the fixed or the moving pivot of the crank. Through this choice of one pole of rotation, relatively simple graphical solutions are possible and up to six precision points can be obtained.

This principle is illustrated in (a) above, where A_1C_1 and A_2C_2 are two positions of the line connecting the moving pivot A with the tracer point C. The fixed pivot A_0 must lie on the bisector a_{12} of A_1 and A_2; the pole P^{12} must lie on the intersection of a_{12} and the bisector c_{12} of C_1 and C_2. The fixed pivot B_0 is selected so as to coincide with P^{12}; consequently, A_0B_0 lies on a_{12}. Positions B_1 and B_2 of the second movable pivot must lie on a circle with B_0 as center. Triangles $A_1B_1C_1$ and $A_2B_2C_2$ must be congruent.

The application of the method is shown in (b) above for four points of coincidence, C_1 to C_4, with the straight line g of the path of tracer point C of the coupler. The pole P^{14} is selected anywhere on the bisector c_{14} of the points C_1, C_4 and is assumed to coincide with the crank center B_0; then P^{14} must also lie on the bisector a_{14} of the yet unknown positions A_1, A_4 of the moving pivot A, which must also pass through the fixed pivot A_0 of the second crank.

Furthermore, angle $A_1P^{14}A_4$ must be equal to angle $C_1P^{14}C_4$ ($= \phi_{14}$), and distance A_1C_1 must be equal to A_4C_4. If two rays—X_1B_0, X_4B_0—are drawn to make angle ϕ_{14}, and an arc of any radius is drawn with B_0 as center, the intersection points A_1, A_4 of the arc with the rays will fulfill this requirement (triangles $A_1C_1B_0$ and $A_4C_4B_0$ being congruent) and also determine the distance AC. The crank positions, A_1 to A_4, must follow one another in the same sequence as the corresponding positions of point C if the path of the motion of point C between the four selected positions also must be approximately straight. To determine position of the moving pivot B, the circle point to B_0, a relationship is considered which is analogous to that shown in Fig. 9, on p 45. Consider the motion of crank BB_0 relative to A_1C_1, with the yet unknown point B_1 as fulcrum. In each of the system positions A_2C_2, A_3C_3, there is a point which coincides with B_0. If A_2C_2, A_3C_3, are rotated so as to come into coincidence with A_1C_1 these points will assume the positions B_{02}, B_{03}; these points are determined by making triangle $A_1C_1B_{02}$ congruent to triangle, $A_2C_2B_0$, and triangle $A_1C_1B_{03}$ congruent to triangle $A_3C_3B_0$. In these rotations the distances of B_{02} and B_{03} from B_1 remain equal to BB_0. This means that B_0 must lie on a circle with B_1 as center. B_1 is then found as intersection of B_0B_{02}. B_1 is then found as intersection of $B_{02}B_{03}$, $B_{02}B_{03}$, respectively.



Method of point position reduction—two poles coincide with fixed crank pivot, five precision points.

2 Since both radius and position of the fixed pivots of the second crank were arbitrarily chosen, this method can be expanded to the synthesis of linkages with five precision points. The five points shown are chosen symmetrical to point C_3 so that the lines c_{15}, c_{24} coincide with the normal through C_3 to line g. Both poles, P^{15} and P^{24}, which must lie on this line, are assumed to coincide with B_0. A ray B_0X_0 is drawn on which the yet unknown second crank center A_0 is assumed to lie. The balance of the construction is analogous to Fig 1 (b) above.

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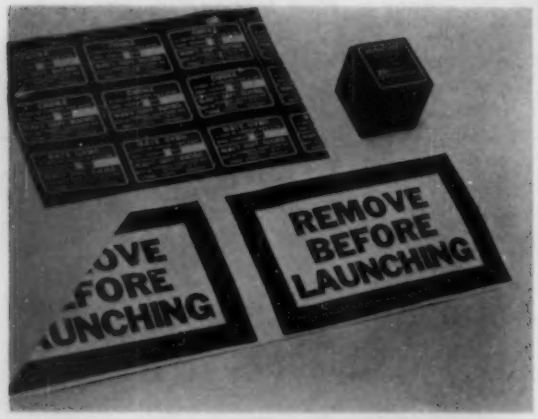
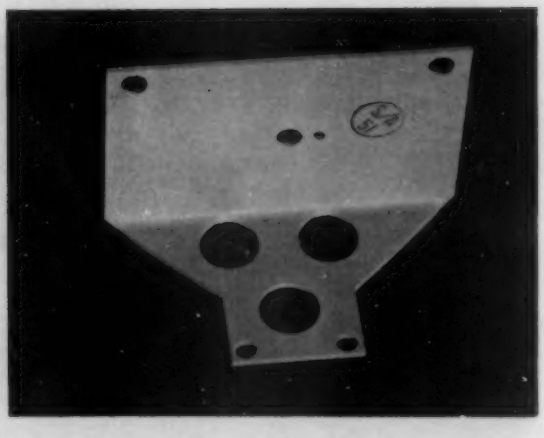
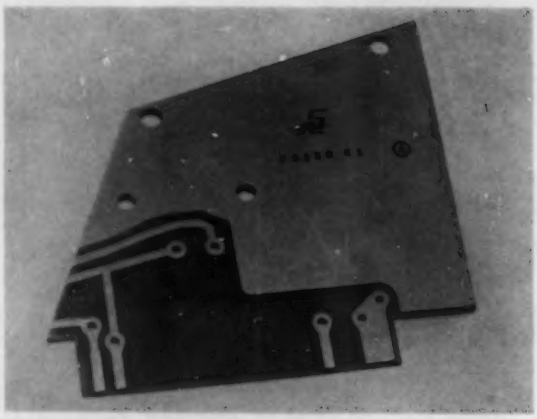
LABEL IT?

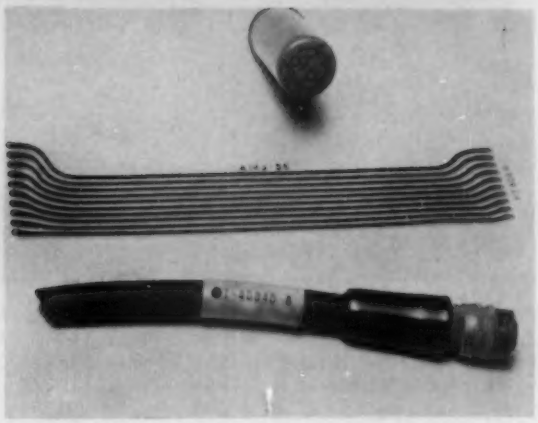


STAMP IT?





ETCH IT?



INK IT?

These are a few of the identification methods compared here in terms of such factors as permanence and adaptability to high-production needs. Author also suggests practical alternates to . . .

THE BEST WAY TO MARK YOUR PART

THOMAS I ARNOLD
Inspection and test manager
Sanders Associates, Nashua, NH

There are disadvantages to marking a manufactured part but the advantages are more important. Marking gives more than display value—it offers specific engineering aids as well. The identification symbol speeds assembly, helps trace trouble with parts, even gives instructions on how to use the part. Other benefits, less obvious: markings can show the completion of production or inspection steps; it will help store and handle parts, keep production records and salvage material.

The drawbacks show why the method of marking cannot be taken lightly. Choice of method must suit the material, shape and function of the part, quantity to be produced, costs allowable, and final appearance desired. The procedure can concentrate mechanical stress, cause corrosion, or interfere with fit of the part. Also, the more-permanent marking methods make deeper notches; and mass-production methods are not as versatile as hand methods.

Before choosing the technique, therefore, first step is to question whether the part needs marking at all. It doesn't when its shape or size is easily recognizable, or can fit only into its specific place in final assembly. On the other hand, marking saves money when parts look similar and can be confused, or a particular model change must be identified. Also, marking may be required by the purchaser—especially if it's the government—or by industry standards. Individual marking sometimes may be avoided by designing parts so that they are distinctive, or by dying an entire lot. Some surface treatments are self-indicating and show that the production stage has been completed. This is why yellow chromate or color anodizing are preferred over colorless versions of the same processes.

Numbers or Letters?

Marking, whether by number or alphabet combinations, or by color code, is usually standardized by the company or by industry and these systems can seldom be scrapped or changed. Number systems are most common. Psychologically, it's best to use two or three numbers in a group. Lettering crams more information into each digit of space but some letters are impractical—notably "I," "O" and "X." These are too easily confused, respectively, with the numbers "1" and "zero," and the multiplication sign. The letter "X" is also reserved for experimental parts. Other letters, "A," "G," "N" and "P" denote assembly, group or part series, and "D" and "R" are avoided because they could be confused with symbols for "Reject" or "Defective." Color-coding by spots or stripe, as used in the electronic industry, takes less space—but coding charts must always be available to decode the colors.

Permanent or Temporary?

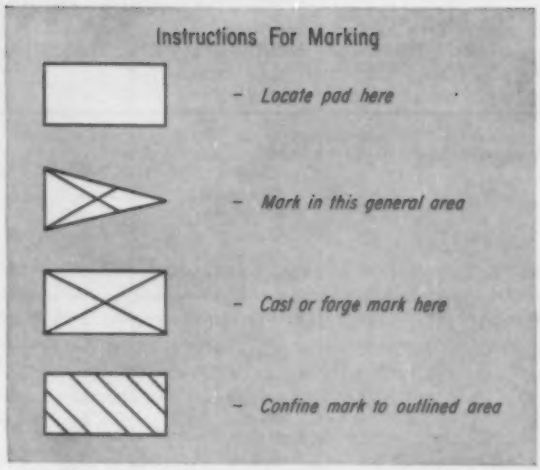
The deeper, more permanent marks cost more; so does closer control of mark depth. In general, less permanent methods like tagging, painting, or marking with crayon are cheaper, more adaptable, and easier. Sometimes marking need only last until the part is put into the assembly —so only the completed product will need careful identification.

Special precautions are needed when temporary markings must last through high temperatures. Inks, paints or other carbonaceous markings that leave heavy carbon or metal residues may locally alter the metal enough to embrittle. They should be removed as soon as they have served their purpose.

GENERAL RULES FOR MARKING

1. Economy is had by planning. Some of the best marking is cast, forged or pressed into the part during fabrication. With long runs, automatic methods give lower tooling costs, especially where markings are identical.

2. Identification should be specified on the neutral axes of the part—on an I-beam section, that would be along centerline of the web. Marks should also be visible after assembly especially when an easy-to-confuse component must be identified. Raised numbers can be integrally cast or forged directly on the part. Indented numbers should be stamped on an identification pad provided for the purpose. Location of the pad—and similar instructions furnished on the blueprint—are designated by standard symbols (see sketch above).


Instructions For Marking
– Locate pad here
– Mark in this general area
– Cast or forge mark here
– Confine mark to outlined area

3. Characters should never be deeper than necessary. A depth of 0.010 in. is a practical maximum—clearly marked characters are legible even if only 0.0006 in. deep. If marks must be legible after some surface wear, deeper marks may be required.

4. Permanent markings should not be put on surfaces that mate or rub against each other. If this is unavoidable, all raised metal and burrs should be removed.

5. Identifications that depress the surface should be put on parts prior to surface treatments; otherwise marking may cut through the coating, leaving an exposed area that needs recoating.

6. Specify the mark needed but not the actual method, unless necessary. Many good suppliers may not have certain marking equipment—lenient specification will allow them to mark the part some other way without sacrificing quality. In the chart, see next page, alternate methods within the same class may be specified on the blueprint.

7. Recommended sizes for characters are normally between 0.060 and 0.160 in. For miniature parts, 0.016 in. is minimum for legibility (you seldom need letters larger than 0.25 in.). When marking is cast or forged, nominal character height should not exceed 0.500 in.

8. Distance from edge of the part should be at least 0.030 in.

PERMANENT METHODS COMPARED

If the part is discolored in use or wear obliterates the markings, then legibility is accentuated by a difference between mark depth and marked surface. Methods that produce this type of permanent marking have their own advantages and drawbacks:

Integrally cast or forged identifications cost little more;

AN APPRAISAL OF THE PERMANENT MARKING PROCESSES

Substitutes are possible for most of these methods. For a given method, first find its class, then look under same class letter in "alternate method" column—any "X" notation is a possible substitute.

METHOD	RESULTING MARK	CLASS	DEPTH OR HEIGHT, in.		ALTERNATE METHOD											
			Min	Max	A	B	C	D	E	F	G	H	J	K	L	M
Integrally Cast	Light	—														
	raised	A	0.005	0.010	X											
	depressed	A	.005	.010	X											
	Intermediate	—														
	raised	—	.008	.035												
	depressed	—	.008	.035												
	Heavy (raised only)	—	.030	.130												
Stamped	Hammer	—														
	shallow	B	.001	.006		X										
	deep	C	.004	.010	X		X									
	Press															
	shallow	D	.001	.006		X		X								
	deep	E	.004	.010	X		X		X							
	Roll															
	shallow	D	.0005	.006		X		X		X	X	X				
	deep	E	.004	.010	X		X		X							
Vibropeened	By hand															
	shallow	D	.001	.006		X		X		X		X				
	deep	E	.004	.010	X		X		X							
	By machine	—	.002	.006		X	X	X		X		X				
Engraved	By hand	F	.0005	.003		X				X						
	By machine	—														
	shallow	G	.0005	.003				X		X	X					
	deep	H	.002	.006		X	X		X	X		X	X			
Arc-burned	By hand															
	shallow	—	.001	.003												
	deep	—	.003	.010												
	By machine															
	shallow	M	.0005	.001												X
	deep		.001	.006												
Scribed	By hand	F	.001	.006		X				X						
	By machine															
	shallow	G	.001	.003				X		X	X				X	
	deep	J	.002	.006		X	X		X	X		X	X			
Acid-etched	shallow	K	———	.0005										X		X
	intermediate	—	.0005	.001												X
	deep	L	.001	.003											X	
Electrolytically Etched	shallow	—	———	.0003										X		X
	intermediate	—	.0003	.0015				X		X	X	X			X	
	deep	—	.001	.003		X										
Electroplated	Deposit	—	———	.0004												X
Blasted	shallow	K	———	.0005										X		X
	deep	G	.0005	.003		X		X		X	X	X				
Branded		—	.001	.010												

they are not limited to depth or height of the character, but part designations must be fixed at an early stage because once cut into the pattern or forging die, the numbers are costly to change. Integral numbers also cause problems when a rough casting is machined to make any one of several finished parts.

Rubber stamping, by far the most common of the handmarking methods, is simplest even though the usual inks at best are considered temporary. In general, the darker inks last better than the whites and light colors. White inks also tend to thicken, become hard to apply, and flake off in use. Special inks for ceramics and glass, which are later fired into the body, are as permanent as the material of the part itself.

THE TYPE FACE ON METAL STAMPS can be varied for different marking needs: sharp—standard unless otherwise specified; round—designed specifically to reduce cracking in stressed parts; flat—wider, more legible letters for given depth.

Vinyl stamps, with a mild acid, can produce a slight etch. After marking with any acid, the parts must be thoroughly cleaned. Etching to just produce a discernible image removes so little of the metal that the process is readily adaptable to weight-sensitive parts like rotating gyroscope elements.

Metal stamping is legible, easy to control in depth, and inexpensive when done automatically. It displaces metal in the depression and leaves a raised burr that must be removed if a flat surface is required. Working the metal leaves residual stresses, particularly in deeply stamped parts. To avoid high stresses, which may initiate failure by stress corrosion, characters on low-stress stamps are made with rounded corners. These stamps leave no sharp edges but are more difficult to use when stamping is by hand.

Hardened stamps are forced into the part by hand-hammering, pressing or rolling. Hand-stamping is most severe on the part. Pressing gives more controllable depth and does not impact the part. Rolling a curved stamp into a flat part progressively presses in the letters. Rolling needs less force than methods that mark the entire letters simultaneously. Production roll markers—standard tools for screw machines—automatically mark each part as it is machined. Specially contoured hand stamps for marking round surfaces such as cylinders are expensive but may not be needed if the mark is placed along one of the straight line elements or on the end of the cylinders.

Acid etching produces a neat mark and when properly done does not excessively weaken the metal. Usual procedure applies a thin coat of stop-off over the whole area. Next, a dam is placed around the area—to contain the acid and prevent acid vapor from flowing over. Then stop-off is cut away from areas to be marked and the exposed metal etched with a strong acid. Etching is easily controlled to within 0.001 in.

Electrolytic etch—electroplating in reverse—requires special equipment but produces a closely controlled image, and is adaptable for either short or long runs. Stencils that expose the etched areas to electrolyte may be cut on a typewriter. Simple etching gives a frosted mark or a black mark by depositing an oxide back on the etched surface. Other adaptations reverse the current to locally plate copper or other metal as a raised mark. Best results require different electrolytes for each metal.

Burned marks include electric-arc etching, which can mark any material that is electrically conductive. Even hard, brittle materials are easy to mark. Heat from the arc alters the structure of the metals, so the method is generally used only on crude material or hard materials. It is common for identifying fixtures, bases and tool handlers but less common for mechanical parts. Another version—hot-branding—is sometimes used with plastic parts, wood or leather goods.

Blast-marking is a fast, cheap, mass-production method. Easily controlled, it makes an image by impingement of shot or grit directed through a stencil. The light images raise the surface slightly by displacing metal. A larger grit size will produce a deeper figure but smaller particles can mark a given area faster.

Vibropeening, scribing and **engraving** are individual piece-marking methods that offer the adaptability needed when each mark is to be different. Vibropeening is the most common freehand lettering method. Legibility varies with skill of the operator and hardness of the tool and metal. Like metal stamping, vibropeening will cut through thin coatings and case-hardened material. Scribing is cheap but depth of the cut or scratch is limited, particularly on hard materials. It also leaves a burr, which varies according to proportion of extruded metal.

Engraving by cutting with a rotary tool gives the most legible marks, especially when the cutter mechanically reproduces from a stencil. It leaves a negligible amount of raised metal but is slow, and too expensive for production in any quantity.

For **REPRINT** of above article, just check P43 on one of the Reader Service cards bound in this issue.

EDITOR'S NOTE: Other recent articles on proper labeling and identification of products and instruments:

These 3 Criteria for Readable Panel Markings, May 25 '59, p 55. Functional panel identification such as instrument labels and counters will do their job best by following these rules for lettering and placement.

Choosing Selector-switch Knobs, Dec 8 '58, p 103. Knob specifications for best readability and easy positioning.

Obtaining Readability in Instrument Dials, Apr '50, p 109. How design with easy reading scales and zero point location can reduce reading errors.

9 Ways to Make Instruments Readable, Feb 3 '58, p 61. Ways to avoid such troublemakers as poor illuminations, illegible numbers, confusing scales and parallax.

Designing the Product to Suit Human Dimensions, Sep '55, p 167. Average human dimensions help design keep controls within reach of operators, and instruments within range of vision for easy readability.

for machines that must think for themselves . . .

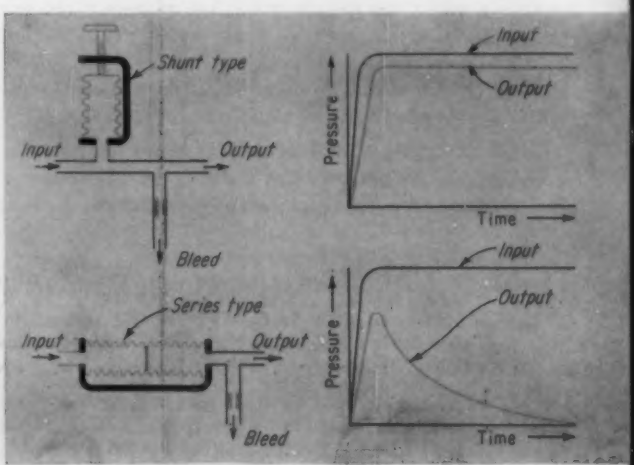
Where explosive atmospheres or other hazards make electrical controls unsafe, then equivalent pneumatic devices—with bellows, nozzles and valves—may do the job. Here is a summary of such devices that have been built and tried in the Robertshaw-Fulton laboratories.

PNEUMATIC VS ELECTRICAL CONTROL ELEMENTS

H S KACHLINE, *manager, mechanical dept*
Eastern Research Center Div
Robertshaw-Fulton Controls Co
King of Prussia, Penna

A new role for pneumatics is envisioned—one in which special air devices do the "thinking," replacing electrical and electronic devices. Air as a control medium has several advantages long recognized by pneumatic-instrument makers. It is nonexplosive, nontoxic, has high power-handling capacity, and stores its own energy for emergency conditions when power is temporarily lost. And pneumatic control elements—in particular those analog types such as orifices, bellows, diaphragms, nozzles, capillaries, and a variety of valves—can duplicate most electrical and electronic controlling functions.

But there are limitations to air for low-power decision-making functions—at least at present. Existing control valves, air relays, and other pneumatic devices are designed principally to perform work, are therefore bulkier and usually more expensive than equivalent resistors, capacitors, relays, diodes, and other electrical equivalents. Air flow is several orders of magnitude slower than electron flow. And



THESE PNEUMATIC CAPACITOR CIRCUITS are equivalent to electrical capacitor circuits. For the circuits shown, input pressure is assumed to be applied quickly and held. Shunt-type capacitor absorbs part of the initial flow, slowing down response, but has no further effect on output. The series type transmits flow and pressure until the back-to-back bellows assembly reaches full extension; then flow is blocked and output pressure decays.

pneumatic response is not always linear, being affected in complex ways by pressure level, rate of flow, air temperature, passage configuration, and length of piping.

Pneumatic-electrical Analogies

Air and electricity are similar mediums in many ways, and much can be learned about controlling with air by studying electronic and electrical devices. The table of **equivalents** (below) makes typical comparisons.

An **electrical resistor** can be simulated pneumatically with an orifice or a tube—pressure differential is analagous to electrical potential. However, air flow is not linear with pressure, there is no simple "Ohm's Law" (flow equals potential divided by resistance) for air. When such an ideal pneumatic resistance is developed (researchers are working on it) the transfer function P_{out}/P_{in}, will be a constant and therefore very useful.

Capacitor equivalent for air can be a bellows, accumulator, tank, length of pipe, or a combination to suit the purpose. A pneumatic series capacitor has two bellows back-to-back, and can store and return flow in either direction. A so-called pneumatic shunt capacitor stores energy in one direction only; can be a single bellows, or other trapped volume. Adjustment for either a series or shunt bellows-type capacitor is possible with mechanical stops to limit travel.

Potentiometer has its pneumatic equivalent in a long cavity, with small cross-section, through which air flows from input to exhaust. A sealed sliding plate covering the cavity has an output connection that "taps off" a pressure inversely proportional to its distance from the input. The cavity must be carefully shaped to insure that output is linear in the desired range of pressure and movement.

Rheostat in pneumatics is essentially a needle valve, but it must have special passage and valve contours to give linear response for flow vs needle-valve position. A contour that gives linear response for one input pressure might be nonlinear for a different pressure. The valve position can be adjusted manually or actuated by a bellows or diaphragm.

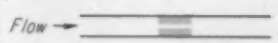
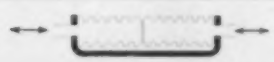
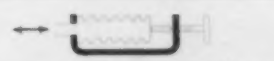
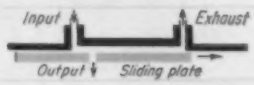
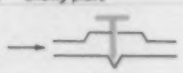
Diode or rectifier can be simulated by a pneumatic check valve (reed valve) which allows flow in one direction only. To prevent backflow, yet not restrict forward flow (particularly at low pressure), a carefully balanced precision valve is needed.

Vacuum tube pneumatic equivalent is a flexible metal bellows that receives signal pressure (grid input), and a nozzle to which supply pressure (plate input) is applied. A flapper, fixed to the bellows, moves with variations in signal pressure. The output, tapped off behind the nozzle, is inversely proportional to distance between nozzle and flapper. The gain (output vs input) is a function of the ratio of the bellows and nozzle diameters, and can be very high. Frequency response, however, drops off appreciably as the nozzle diameter is decreased.

Connecting Control Elements

Pneumatic as well as electrical circuits have terminals that must be connected. The length and cross-section of connecting lines, whether electrical or pneumatic, affect "capacitance" volume—a measure of the ability of a system to store up the flowing medium. Pneumatic tubing—and electrical wiring—must have a large enough diameter to carry the maximum flow, yet not be so large that excessive capacitance will delay transmission of the signal. A system with small line volumes will respond faster, operate at higher frequencies, than one with large volumes.

QUICK GLANCE AT EQUIVALENTS

ELECTRICAL	PNEUMATIC	
Resistor	Tube restriction	
Capacitor: Series	Bellows: Back-to-back	
Shunt	Adjustable volume	
Potentiometer	Fixed restriction, movable tap	
Rheostat	Needle valve	
Diode	Reed valve	
Vacuum tube	Nozzle and bellows	

EDITOR'S NOTE: Air for control has been the topic of these previous articles:

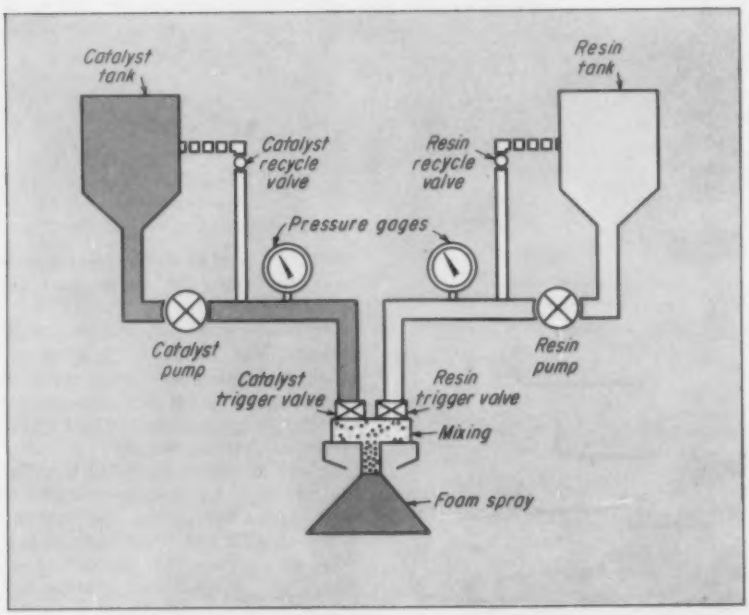
Valve with a Memory Handles Logic Circuits, May 26 '58, p 76, gives detailed descriptions of several types of "momentary" valves that can perform the digital function of MEMORY; included are sample circuits.

Design of Pneumatic Relay Circuits, Mid-Oct '56, p J-8, describes pneumatic circuits that can replace electrical for motor starting and other controls, and gives simple pneumatic equivalents for relays, pilot lights, fuses, switches and voltage reducing transformers.

Moleculonics, Jan 18 '60, p 81, is a short abstract from the book **Moleculonics** (published by Modernair Corp), and shows typical pneumatic logic elements for the digital functions AND, OR, NOT and MEMORY.

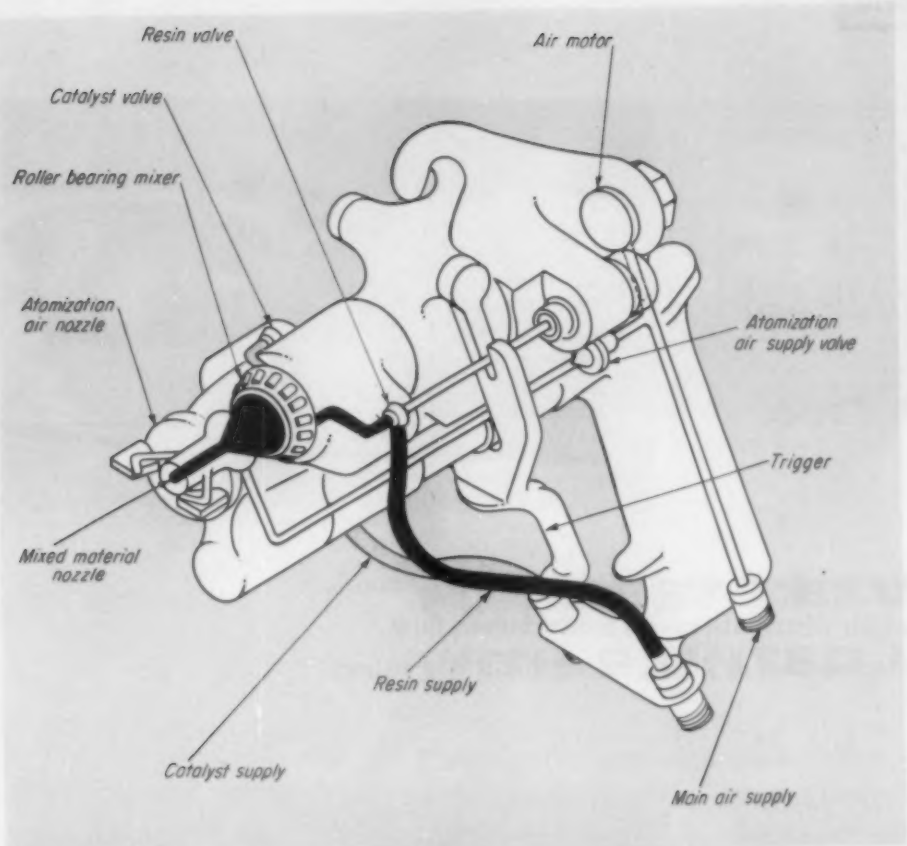
Air Masters Runaway Foam

This system keeps two reacting liquids apart until the spray gun is triggered. Then air goes to work fast: (1) spins roller bearings that do the mixing; (2) shoots out the resulting foam.

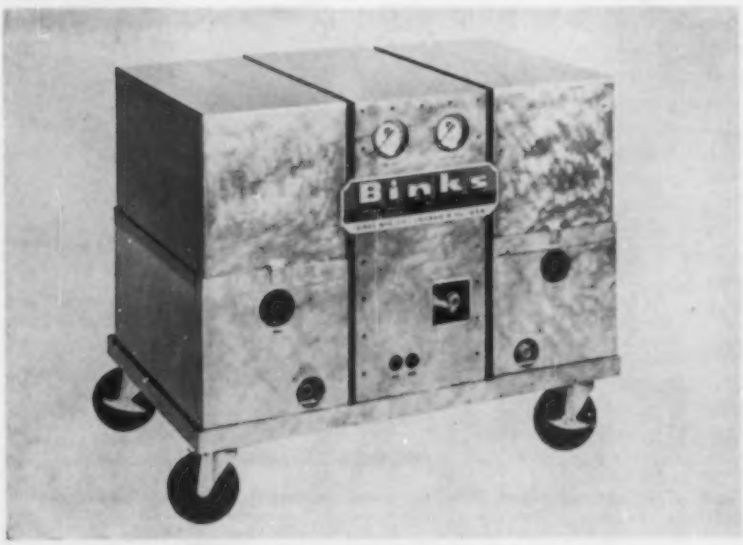


STORED RESIN is heated to desired working temperature and delivered with the catalyst by controlled-volume pumps. The pumps deliver proportioned fluid streams at preset ratios. Recycling valves return these streams to their respective storage tanks until the spray-gun trigger valves are opened. Then, proportioned liquids are delivered to the tapered roller-bearing mixer and are discharged as reacting liquid. Even if temperature, viscosity, or head pressure vary, the pumps will continue to move the predetermined volume within the limit set by the recycling valve.

PS . . . The double-duty spray gun and its supply reservoir are designed to apply mixes such as those giving poly-urethane foams and a variety of coatings. Primary use is for coating or spraying-in-place with fast-reacting foam plastics—polyurethane foams with 4-sec reaction times have been successfully sprayed. Premature foaming is prevented by keeping liquids separated until time of application. "Turbulator" spray gun and "Formulator" reservoir made by Binks Manufacturing Co, Chicago.

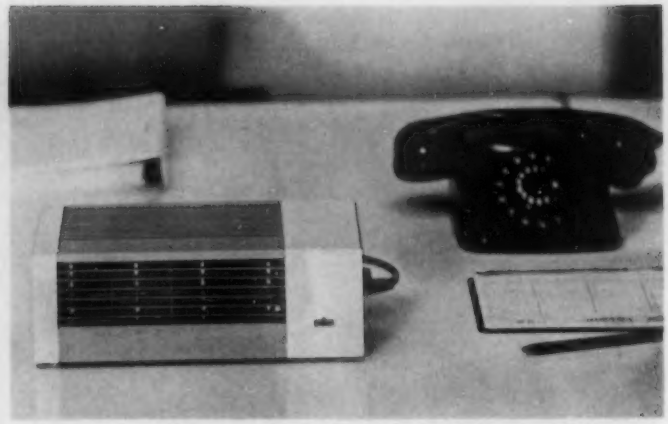


SPRAY GUN contains two trigger-operated liquid valves, an air valve, an air motor, mixer and atomizing spray nozzle. The air motor, operating at 5000 rpm, is coupled to the inner race of a tapered roller bearing, which does the complete mixing job. Ratio between size of inner race and rollers of tapered bearing results in roller rotational speed of 20,000 rpm. Both liquid phases are forced through the bearing; as the bearing turns, the liquids are mixed and delivered to the spray head. Bearing produces excellent mechanical mixing in small space.

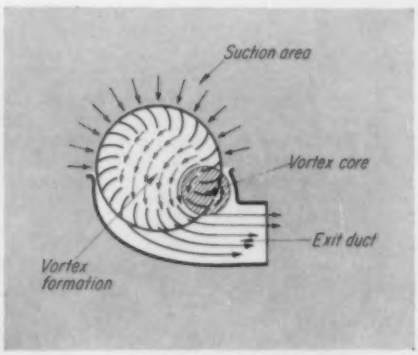


RESERVOIR UNIT consists of a non-pressurized container for each reactant. Motor-driven 2-stage pumps deliver liquids to the spray gun on a volume-by-weight basis, which can be adjusted to allow handling of a wide range of mixing proportions. Delivery pressures at the spray gun range up to 200 psi; delivery rates, up to 10 lb per min. Since reservoirs are unpressurized, they can be refilled as often as required without equipment shutdown. A solvent tank is also included, to clean the units and prevent hardening of the material in the lines or spray nozzles.

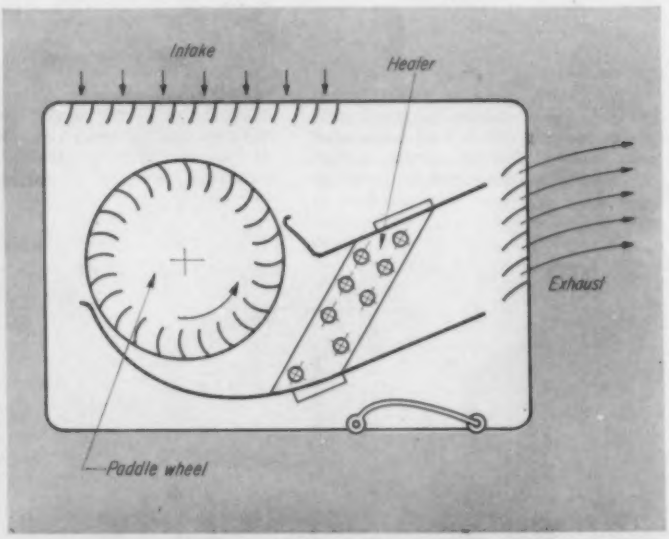
Paddle Wheel Fans the Heat



Slow-speed tangential fan has low noise level, produces smooth stream for improved air distribution. Its nonturbulent flow allows standing the fan on desk or floor without disturbing papers or raising dust.

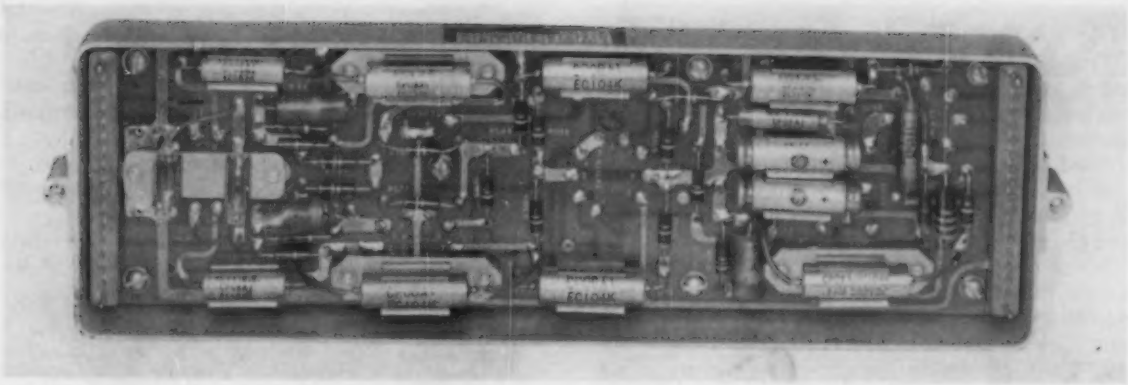


TANGENTIAL DESIGN of the fan provides stable pressure-volume relationship without pulsations. The heating elements and non-eddy-forming diffuser convert the velocity head into static pressure without decreasing the volume of air. Irregular spacing and slant of heating elements give uniform heat transfer by balancing out uneven velocity pattern across exhaust duct. Careful matching of fan, heating elements and diffuser results in smooth air stream that skims over floor or surface of the table.



INTAKE AND EXHAUST DIFFUSER smooths air passage through heater to provide maximum projection of warmed air. Adjustable stand permits heater to tilt or lie flat. Mounted on wall, heater gives better mix by sucking air in through open bottom as well as top.

PS . . . Compact fan moves more than 1 cu ft of air per second, has a maximum reach of 26 ft at max velocity. Switch provides for selection of 500-, 1000- or 2000-watt heating elements. Thermostat control incorporates an overheat protector that cuts off heat when ambient temperature reaches 85 F. Room heater is built by Max Braun Co, Frankfurt/Main, Germany.



Good design calls for: screw supports on close centers, heavier components held in clips, component designation printed, insulated components as crossovers.

FOR BEST RESULTS WITH PRINTED WIRING

First, say the authors, make sure that etched laminate will be better than conventional wiring for your application. They then give answers for specific design problems you face when printed circuit boards are the choice.

CHARLES F DWYER,
mechanical design engineer, and
A F SOLARO, *staff engineer*
ITT Federal Div, Fort Wayne, Ind

Design Limitations

In deciding to use printed circuits instead of point-to-point wiring:

Current values higher than 15 to 20 amps present problems.

Component weight is a factor—flexibility of printed wiring board requires multiple supports on close centers when weight concentrations reach 0.05 lb per sq in.

Temperature extremes affect the strength of boards—when higher than 175 F or lower than —60 F.

Multiple crossovers in complicated circuits add complexity and cost.

Printed circuits are compact, light, reliable, simple, uniform. They cut cost in production runs of 25 units or more. The savings can come from: elimination of expensive hand wiring, reduction of assembly time, and less need for trouble shooting.

But printed circuits will not replace all conventional wiring. Production facilities are required for assembly, inspection and testing. Close sampling is necessary. The circuit must be final, components must be reliable, and location of parts cannot be changed. Rework of defective parts is generally more difficult. And printed circuit techniques, if applicable, must be introduced early in the development program—not brought in as an afterthought.

These factors must be evaluated in deciding on printed wiring for an application: (1) Quantity to be produced; (2) operating conditions, such as heat, shock, vibration; (3) conductor current; (4) circuit complexity; (5) space available; (6) relative cost of components and design procedure; (7) specialized facilities and personnel required.

Quantity Requirements

Minimum quantity needed to give a cost advantage depends on both the design and the facilities available. With our experienced drafting group and well-equipped

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production setup, a quantity as low as 25 can be handled economically for small and fairly simple circuits. Break-even quantity is higher for large, more complex boards; probably still larger if the etched board were purchased.

Operating Conditions

Temperature extremes affect strength of the board and its ability to support component weight. For temperatures beyond 200 F or −60 F the board should be relieved of all strain introduced by heavy components.

Board material, thickness and spacing of supports depend on size of the board and weight of components it has to support. Shock and vibration also introduce problems of rigidity and spacing of supports.

Where components are few and small, and vibration is not a factor, 1/16-in. phenolic boards may be used with supports spaced 3 or 4 in. Heavier components may require thicker boards of stiffer compositions (epoxy or silicone glass) to prevent "diaphragming" under steady loads, or to reduce amplitude of vibration.

For a maximum component density of about 0.05 lb per sq in., and a natural frequency above 250 cps, here is a good rule of thumb for the spacing of screw supports:

Board thickness, in.	1/16	3/32	1/8
Teflon glass	1	1½	2
Epoxy or silicone glass	1½	2	2½

Components should be tied down to prevent deflection under vibration or shock that might cause fatigue failure in the leads. Fuse clips or component holders can help hold heavier parts in place.

Conductor Current

For small currents of an amp or less, heat generated is no problem; a conductor 0.0014 in. thick and 1/32 in. wide —normally the smallest available—on a 1/16-in. board will safely carry 5 amp without generating enough heat to affect the bond or soften the board. Thicker and wider conductors increase current capacity:

Conductor Thickness	0.0014	0.0028
Current per 1/32 width	5 amp	8 amp

Thicker conductors, heavier boards, or addition of heat sinks can increase heat dissipation beyond these levels without damaging the bond. Where current values may vary, conservative design will call for conductor widths 50% greater than these recommendations.

Conductor thickness is specified in terms of oz per sq ft, ranging from 1 oz (0.0014 in. thick) to 7 oz (0.0094 in.). Since most applications involve low currents the 0.0014-in. thickness is the most common. Use of heavier thickness to carry more current may bring problems of convection cooling and ventilation.

Simplifying the Circuit

Initial layout of a printed circuit board starts with a schematic circuit diagram. The primary consideration is to reduce the number of random, disorganized wires to a pattern which can be applied to a flat surface with all crossovers eliminated. A good way to start is to prepare templets for components, and make free-hand point-to-point wiring diagrams until crossovers are minimized.

Printed circuit boards are clad on one or both sides. Circuit complexity that requires using both sides of the sheet will add cost in design and manufacture to obtain registry between the two patterns. Circuit crossovers are the the major problem.

If possible, all conductors should be on one side of the panel, all components on the other side. Use insulated components such as diodes, resistors and capacitors to bridge the conductors and minimize crossovers.

If both sides of the board have to be used, interconnect between the two surfaces with feed-through terminals, plated-through holes and eyelets.

Don't overlook metal foil patterns for shielding or grounding. Watch for density of electronic components that may bring a problem in heat dissipation.

After a suitable circuit layout is obtained, then check the conductor size and spacing. Keep the area of the printed circuit board to a minimum.

Drafting Procedure

In converting a schematic to a circuit pattern suitable for use on a copper-clad laminate board, the drawing should be made on a dimensionally stable material, such as Mylar film. It is drawn to an enlarged scale, using a uniform grid for holes and conductors.

Hole positions on the drawing should be held to a tolerance of 0.005 in. Line widths and locations that are not critical may vary 1/32 in. This drawing should also show and identify the components. In addition to plan views, show any other views necessary for interpretation of the drawing.

The printed circuit master is an inked or tape reproduction of the circuit portion of the layout, and the printed wiring board is prepared directly from this master. Drafting must be to close tolerances, with special attention to accumulated tolerances. Typical errors are improper registration: hole to pattern, connector finger to edge of board, and side to side.

Masters are made on polyester film, such as Mylar, that is flexible, strong and transparent. Small circuits are made on film 0.005 in. thick; larger layouts, or circuits requiring high accuracy, are drawn on 0.0075 in. film.

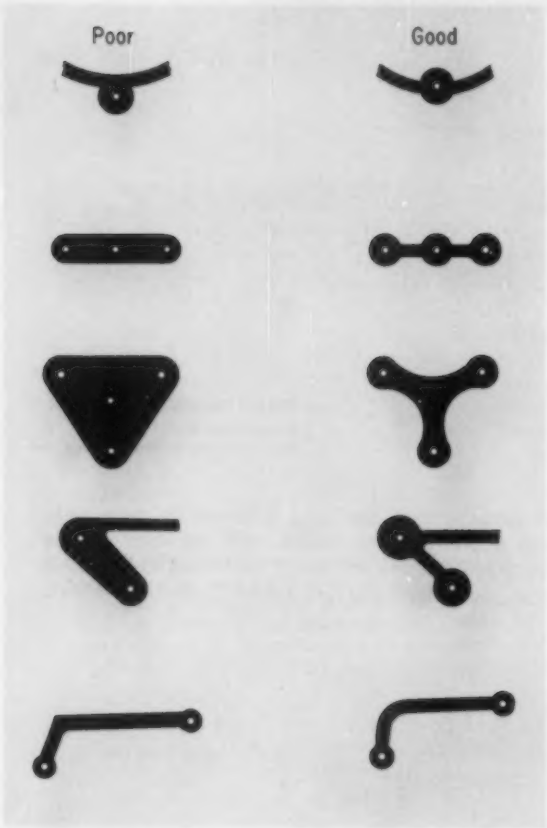
Inks used are acetate base, with good adhesion and high opacity. They dry with a dull surface finish which prevents light reflection during photographing.

- Diameters for holes, terminals, screw clearances and eyelets should be at least 75% of board thickness.
- Distances between holes, or between the edge of a hole and edge of the board should be at least 1½ times the board thickness.
- Line-widths should not be less than 1/32 in.; spaces between lines should be at least 1/16 in.
- Conductor length should be minimum.
- Conductor intersections forming angles less than 135° should be reinforced with fillets having a radius equal to the conductor width. Intersecting lines forming angles greater than 135° do not require fillets unless within 1 in. from a pad.

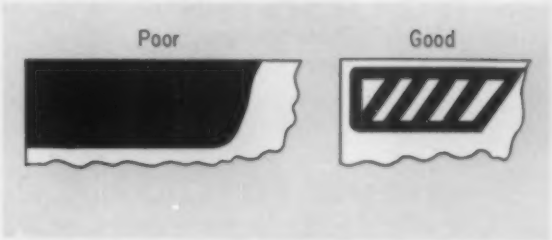
Hole Costs

A basic rule in piercing laminated plastics is that hole diameter should at least equal stock thickness, and spacing between holes should be 1½ times the stock thickness. Smaller holes must be drilled at higher cost. Sharp-

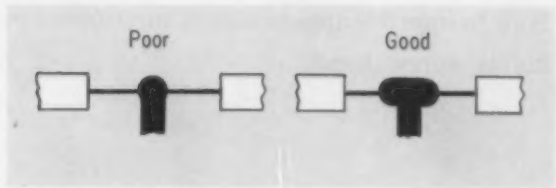
Design guide for laying out printed wiring circuits



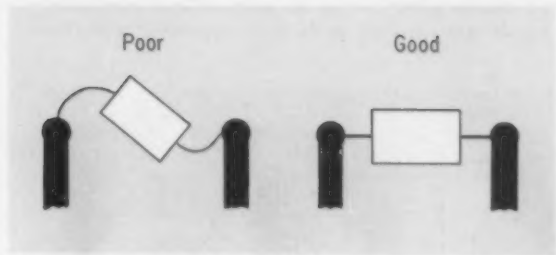
Conductors



Unused Areas



One wire to a hole



Align components

cornered holes and cut-outs should be avoided since they are not only costly but weaken the printed board.

Holes should be identified for assembly with numbers placed on the art work and etched in copper on the board. Part numbers and other designations also should be included for permanent identification.

Terminal pads where electrical connections are made to the etched wiring serve as drilling symbols, and as assembly aids. Holes in terminal pads that take only a component lead wire should be 0.005 to 0.008 in. larger than the lead diameter, and generally not less than $\frac{1}{3}$ the material thickness. The outside diameter of the pad should be at least $\frac{1}{32}$ in. larger than the hole.

Terminal pads which received eyelets should have an outside diameter $\frac{1}{32}$ in. larger than the head or flange of the eyelet; diameter of eyelet head is usually twice the body diameter.

Eyelets should be used where large or heavy components are to be mounted by their leads, or where frequent component replacement is anticipated. Make certain that crimping does not crush the board or terminal pad. Eyelets can also be used to make connections through to the wiring patterns on the other side of the board.

In bending leads of components for printed circuits:

- Use $\frac{1}{16}$-in. minimum bend radius.
- Keep $\frac{1}{8}$-in. minimum lead length from body to start of bend; do not deform or break seals on components.
- Avoid loops or special bends to provide assumed relief from damage to parts during assembly.
- For supported parts, lead length for the free end should be as short as possible.
- Axial-lead parts should be mounted with the axis of the part in line with centerline between mounting holes.
- Keep jumper wires to at least 1 in. long and use solid conductor instead of stranded.

For REPRINT of above article, just check P41 on one of the Reader Service cards bound in this issue.

EDITOR'S NOTE: These earlier articles include design data directed to industrial applications.

Printed Wiring for Inustrial Service, Aug '56, p 167. Thorough evaluation of basic systems, conductor and materials; special problems presented in selecting components; design recommendations in selecting base material, conductor size, prototype method.

Printed Circuits for Electrical Equipment, Mid-Oct '56, p 128. Data on paper-base phenolic and glass-fiber board materials, 25 specific design considerations; tooling; production and soldering problems.

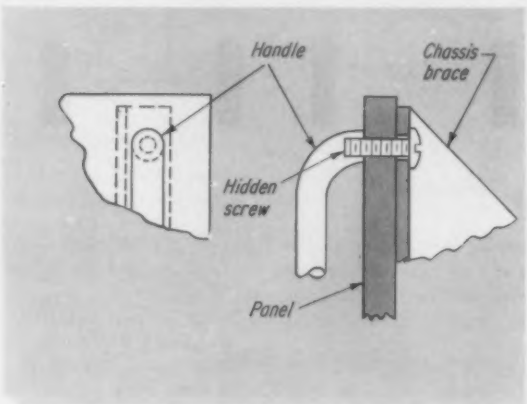
Printed Circuit Rotors for Dc Motors. Mar 16 '59, p 54. Design specifications for a rotor with no iron core, no conventional windings.

10 ways to CONCEAL FASTENERS

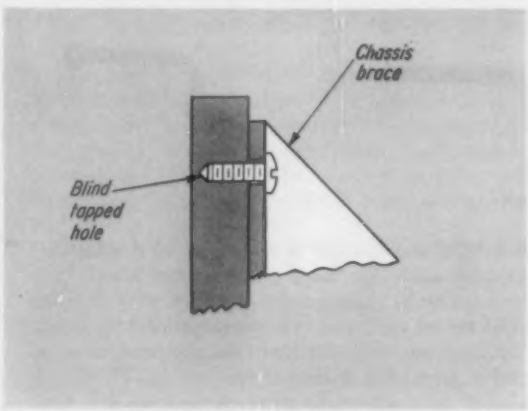
How to improve appearance of instrument panels by hiding screw heads.

FRANK WILLIAM WOOD JR
design engineer
Vitro Laboratories, Silver Spring, Md

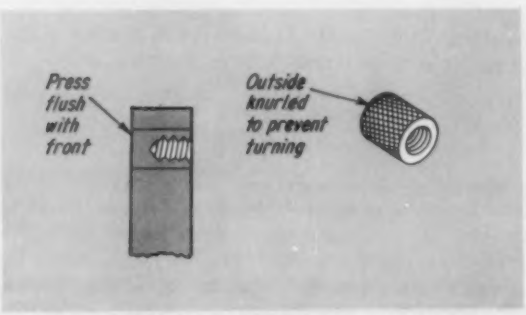
The appearance of an otherwise good-looking instrument panel is often spoiled by screw heads distributed in an uneven pattern across the panel surface. The following designs illustrate methods of improving appearance by subduing and concealing fasteners. In some cases, applications of these designs will not only improve appearance but also will reduce fabricating and assembly costs. Sometimes you get tamper protection as well.



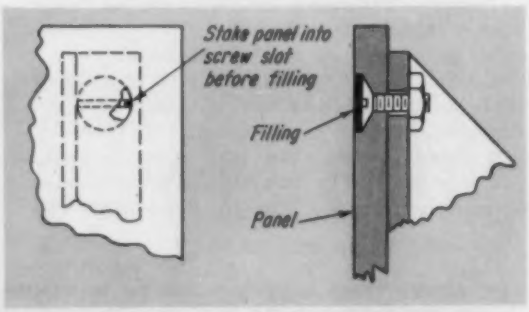
1 DOUBLE-DUTY SCREW attaches chassis to panel, is concealed by handle . A bonus is reduced fabrication and assembly time.



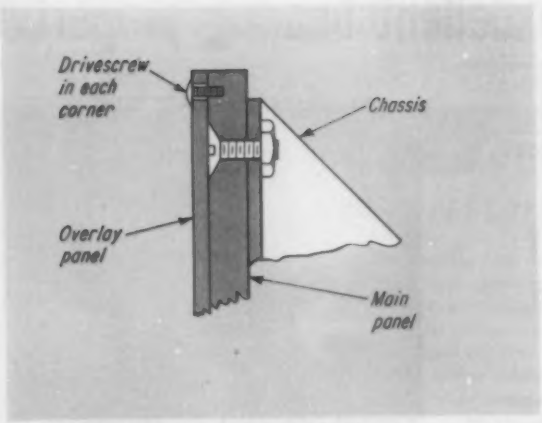
2 BLIND HOLE in panel conceals screw. This method is best suited for thicker panels, when adequate depth can be obtained without close tolerances.



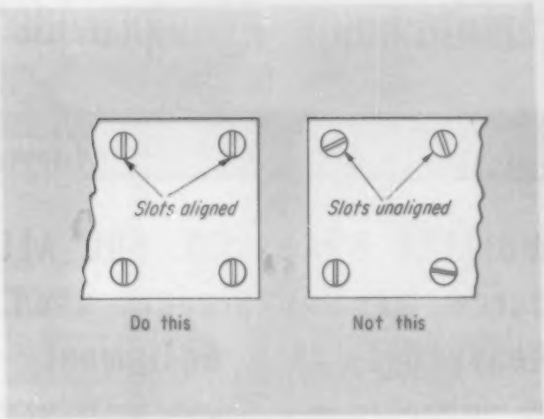
3 TAPPED INSERT pressed into panel is sometimes more economical than blind-tapped panel.



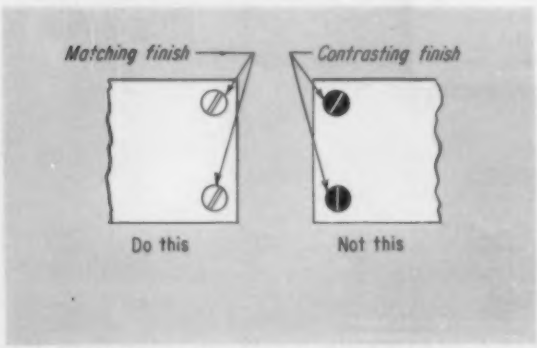
4 RECESSED SCREW HEAD is concealed with an epoxy resin before panel finish is applied. To prevent loosening of screw, the panel should be threaded. This thread, in conjunction with staking, locks the screw securely in position.



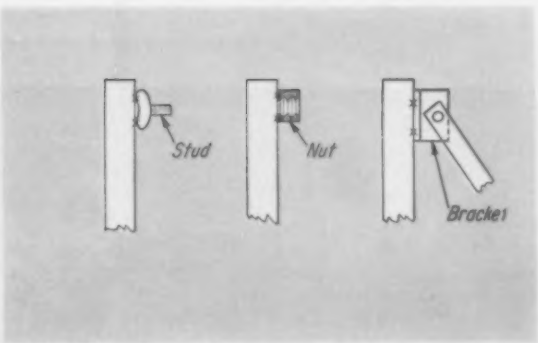
5 "OVERLAY" PANEL conceals all front-panel hardware. Overlay panel offers no support for components and in many cases is attached with pressure-sensitive adhesive. All markings and nomenclature for controls can be carried by this panel.



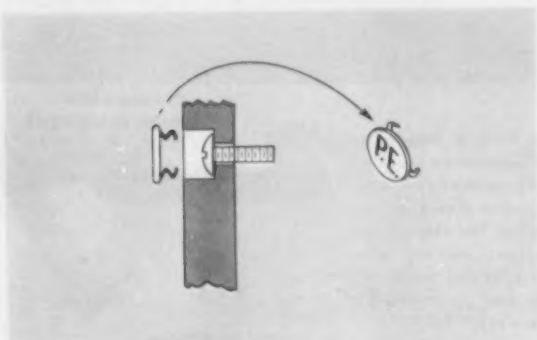
6 ORIENT SCREW-HEAD SLOTS in same direction to subdue detracting appearance of screw heads.



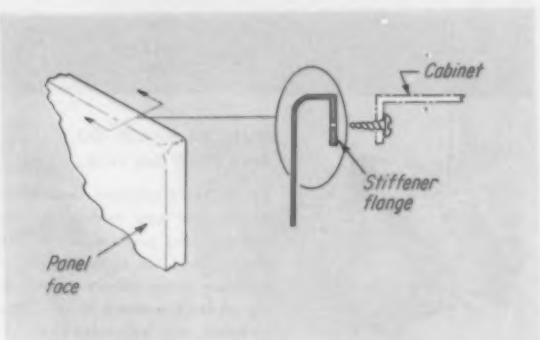
7 MATCHING HARDWARE FINISH to that of the panel effectively subdues hardware appearance. A familiar example of this is the black oxide finish commonly used on panel-meter screws.



8 SPOT-WELDED STUDS AND NUTS are commercially available for use on steel panels. Or, alternatively, special brackets can be used.



9 SNAP-IN "PLUG BUTTON" fits into counterbored recess to conceal screw head and also provide corporate or product identity.



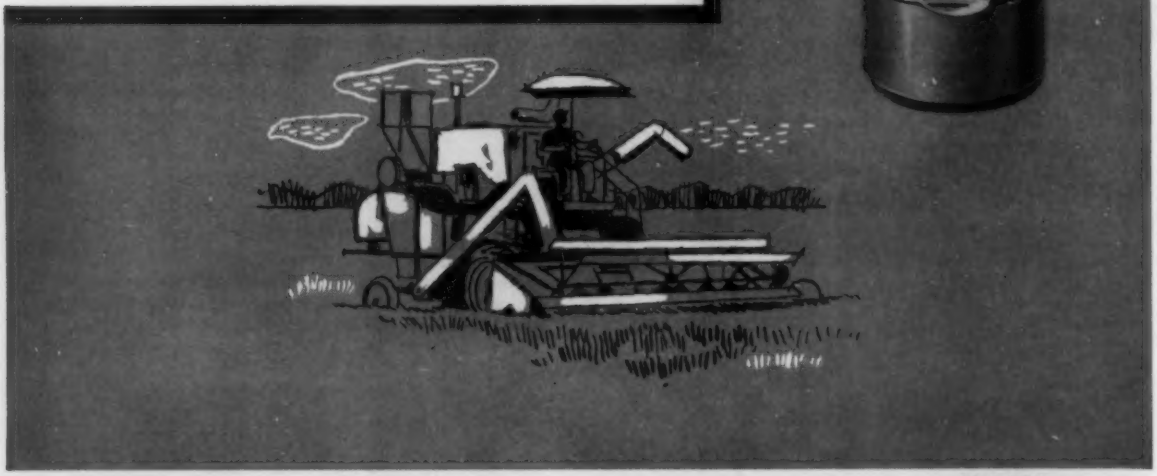
10 SHEETMETAL STIFFENER FLANGES can be integral, as shown here, or separate when panel material cannot be formed. Sheetmetal screws hold panel.

two more cases where PARTS PRODUCED FROM provide excellent bearing properties

CASE HISTORY

MUELLER BRASS CO. 600 ALLOY screw machine product used in heavy duty farm equipment

This heavy duty planetary pinion shaft, made as a screw part from tough "600" series bearing alloy, was the answer to a continuing wear problem encountered in the driving mechanism of heavy-duty farm equipment and big trucks. The part is machine produced to exacting tolerances and all necessary finishing operations are done by Mueller Brass Co. so the pinion shaft is ready for installation when received. Since "600" alloy parts have been installed, no operating failures have been reported and the shafts have proved far superior to the material formerly used.



MUELLER BRASS CO. ANALYSIS SERVICE

You get sound, unbiased advice on the one best method of making your parts because Mueller Brass Co. is the only fabricator in the country offering all these methods of production. An experienced Methods Analysis Department has at its command a complete knowledge of the advantages and limitations of each production process. This unique technical service is your assurance of getting the best product at the best price . . . made the one best way!

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PLASTIC INJECTION MOLDING

MUELLER BRASS CO.

MUELLER BRASS CO. 600 ALLOY

and maximum wear resistance in tough applications

CASE HISTORY

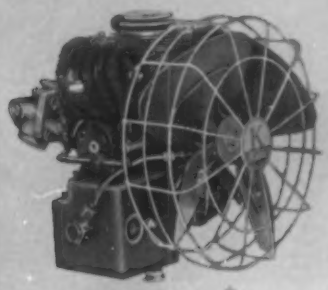
MUELLER BRASS CO. 600 ALLOY forgings used in aviation air compressors

Analyzing the job requirements of Walter Kidde & Company, Inc., for a main driving cam component to be installed in a reciprocating type of aircraft air compressor, Mueller Brass Co. Methods Analysis Engineers decided on a forging fabricated from "600" alloy as the most practical method of production. Since the cam forms the prime component of the driving mechanism, it must have good bearing wear surfaces and because the compressors are used in the aviation industry, the cams must be completely dependable. The close grained, strong forging that resists combination compressive and tensile stresses was the answer.

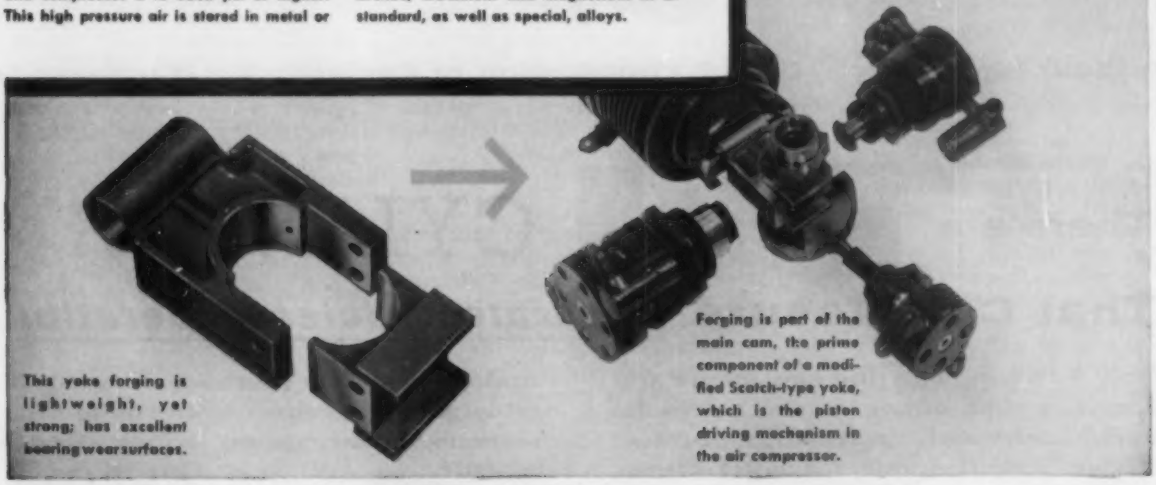
A typical compressor takes in ambient air and compresses it to 3000 psi or higher. This high pressure air is stored in metal or fiberglas containers until needed for actuation of pneumatic system components such as solenoid control valves, brake valves, manual control valves or actuators. These and other pneumatic units retract the entrance door, operate landing gear, wheel brakes, nose wheel steering systems, propeller brakes or perform other functions.

Aircraft in which Kidde compressors are installed include the Boeing 707, the Douglas DC-8, the Lockheed Electra, the Fairchild F-27 and various military aircraft.

Mueller Brass Co. produces press, hammer or cored forgings of any practical shape from a few ounces to 150 lbs. in brass, bronze, aluminum and magnesium in 27 standard, as well as special, alloys.



Aircraft air compressor equipped with hydraulic drive delivers air compressed to 3000 psi at the rate of 6 cfm.

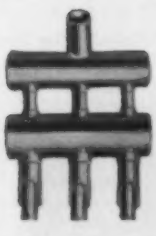


This yoke forging is lightweight, yet strong; has excellent bearing wear surfaces.

Forging is part of the main cam, the prime component of a modified Scotch-type yoke, which is the piston driving mechanism in the air compressor.

POWDERED METAL PARTS

SAND CASTINGS



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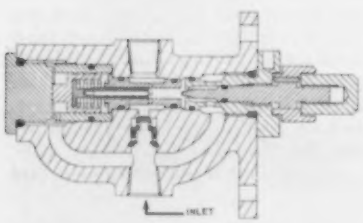
Full-molded, jacketed, notched V-belt . . .

is said to run quietly and without vibration over smaller pulleys, as small as 1⅜ in. dia. Molded V-belt is reinforced by high-strength member cords and covered by rubberized fabric jacket. Cord is micro-positioned and formed into arch through patented molding process, resulting in increased sidewall pressure, which provides more grip, little or no slippage and more uniform pitch. Available in standard fhp sizes, with fhp ratings equal to or exceeding ratings of standard fhp V-belts. Priced slightly higher than standard fhp V-belts. Delivery for those V-belts for which molds are in stock, about 2 to 4 wk. For other sizes, delivery is about 6 to 8 wk. **Raybestos-Manhattan Inc, Manhattan Rubber Div, Passaic, NJ.**

Circle 300 on Reader Service Card



Low-flow regulator . . .

controls flow as low as 35 cc per min. Built-in check valve provides free flow with min pressure drop in reverse-flow direction. Infinitely adjustable between 2 and 90 cu in. per min. Positive lock is reported at any flow setting. Over-all pressure drop will vary from 15 psi at 2 cu in. per min to 40 psi at 90 cu in. per min. Flow accuracy varies from 10% for 2 to 5 cu in. per min. to 5% for 20 to 90 cu in. per min., with 1000-psi pressure differential. Max operating pressure is 2000 psi. For ¼-in. NPT pipe. List price, $55. Immediate delivery. **Fluid Power Accessories Inc, 2051 Railroad Ave, Glenview, Ill.**

Circle 301 on Reader Service Card

Subminiature limit switch . . .

for applications requiring fixed number of revolutions or fractions thereof of rotating shafts, such as servomechanisms, which need mechanical stop protection as well as actuation of electrical switches at each end of preset limit. Switch supports four 11SM1 microswitches, two at each end of slide bar, facing one another. Presetting of slide bar and positioning of switches results in one switch being normally closed, the other normally open. When pinion reaches stop collar, further shaft rotation deflects slide bar to actuate both switches on that end. Use of 21- and 22-tooth pinions allows about 1° adjustments throughout range of 32 turns or 11,520°. In small quantities, about $40 each. Delivery, 1 wk to 10 days. **Arch Instrument Co Inc, 101 Holmes St, N Quincy 71, Mass.**

Circle 302 on Reader Service Card

Pressure controller . . .

can be operated manually, by servo, or using both simultaneously. Integrated system combines adjustable, sensitive mechanical pressure regulation, micro-adjustment, and servosystem that adjusts regulator to desired pressure and compensates for subsequent drift. Continuous and independent indication of pressure maintained is provided by photoelectric null-indicator device. Rapid traversing between control points is possible because of three-speed control. For servo operation, controller is used with photoelectric barometer. Manual control allows use with visual-sighting barometer or other pressure indicator. Offered in two ranges: 0.5 to 40 in. mercury range (for calibration of altimeters and similar instruments) is priced at $1325; 0.8 to 100 in. mercury range (for calibration of air-speed indicators) is priced at $1375. Establishes and maintains desired pressure within 0.0005 in. mercury or less. **Hass Instrument Corp, 6173 Branch Ave E, SE, Washington 23, DC.**

Circle 303 on Reader Service Card

Floating right-angle gear drive

for applications requiring power transmission at right angles has 1:1 ratio. Drive is installed by assembling gears and housings around shafts. Floating feature of unit permits self-alignment and automatic adjustment on driving and driven shafts. Standard unit is for 1-in. shaft. Other units available. OEM price, $24. From stock. **Tol-O-Matic Inc, 246 Tenth Ave S, Minneapolis 15.**

Circle 304 on Reader Service Card

Add-subtract pulsing device . . .

is heavy-duty unit for bidirectional measuring and/or control applications. Said to withstand shock and vibration without registering false counts. Standard measuring wheels can be connected to shaft of rotary sensing unit to convert forward and backward mechanical motion into corresponding electrical pulses, up to 1200 counts per rotation, in either direction. These positive or negative pulses are then fed to remote digital, reversible counters, controllers or readout devices. Measures 3½ in. dia x 2 in. long with ¼ in. shaft. Weighs 20 oz. Starting torque is about ½ in.-oz. Components are rated for 5-yr life. Speed range is zero to 2000 rpm. Output is negative 6-v pulse of constant amplitude and duration. **Dynapar Corp, 7312 N Ridgeway, Skokie, Ill.**

Circle 305 on Reader Service Card

Oiltight limit switches . . .

for high-speed, precision production machines are sealed to check seepage of oil, coolants, moisture and abrasive grit. External seals are located at operating-shaft bearing and between cover plate and

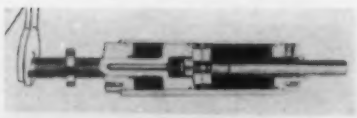
contact assembly. Internal seal between operating head and switch base is additional protection. Contacts are enclosed, but visible. Switches, for surface and flush mounting, are calibrated to control tolerances, producing identical operation of all switches. Further flexibility is offered by 14 different operating heads, which can be mounted in any of four positions. Rotary levers can be positioned anywhere through 360° circle. **Cutler-Hammer, 296 N 12th St, Milwaukee.**

Circle 306 on Reader Service Card

Excessive vibration is detected

in rotating and reciprocating machinery by monitor using pneumatic lines for control power. Previous version was made only in electric-control models. Operates by opening bypass valve in pneumatic line and exhausting line pressure to atmosphere. Detects increased amplitude of vibration caused by physical increase in motion; increase in velocity based upon how fast device shakes; acceleration increases caused by degree of rapidity that vibration changes direction. **Aeronautical and Instrument Div, Robertshaw-Fulton Controls Co, Santa Ana Freeway at Euclid Ave, Anaheim, Calif.**

Circle 307 on Reader Service Card



Adjustable-stroke cylinder . . .

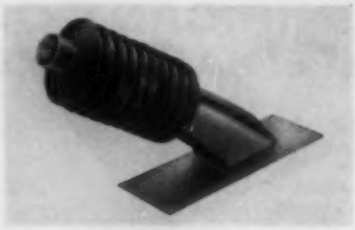
can be shortened or lengthened, with micrometer accuracy, by turning rod. Available for 150-psi air service; up to 500-psi hydraulic service in 1½ to 8-in. bores with standard, 2-to-1 or oversize rods. **Ortman-Miller Machine Co, 19 143rd St, Hammond, Ind.**

Circle 308 on Reader Service Card

4-way dual solenoid valve . . .

provides three-position operation, with closed center position (when both solenoids are deenergized), at which time flow is blocked to all orifices. Locks cylinder piston at any point of stroke. Instantaneous in operation, valve uses two moving pilot cores and four flexing diaphragms. Available with ¼- or ⅜-in. pipe connections. Handles air, water and oil from 10 to 250 psi on ac or dc voltages. **Automatic Switch Co, Florham Park, NJ.**

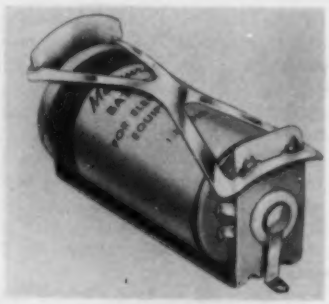
Circle 309 on Reader Service Card



Neoprene-base material . . .

that is impervious to oil, grease and water is used to fabricate sleeves and boots that meet MIL-C-20696. Piston rods, rams, jacks and entire drives are fully protected while intricate mechanisms move horizontally, vertically, back, forward and at any required angles. Material is said to withstand —80 to 220 F without cracking. **A & A Mfg Co Inc, 712 S 12th St, Milwaukee 4.**

Circle 310 on Reader Service Card



Vibrationproof battery holders

for D-size mercury batteries are available insulated at one end only or at both ends, to permit floating of voltage supply. Made of phosphor bronze and is available with nickel, gold, or silver plating. **Cambridge Thermionic Corp, 445 Concord Ave, Cambridge 38, Mass.**

Circle 311 on Reader Service Card

Mercury-wetted contact relay

for high-speed switching offers speeds to 100 operations per sec. Contacts are rated 250 v-amp, 500 v max; 5 amp max with suitable protection. **Adams & Westlake Co, Elkhart, Ind.**

Circle 312 on Reader Service Card

Modular in-line switch . . .

replaces rotary 10-position or octal switch units in ¼ panel space normally needed. Finger-controlled switch provides for 10-position, SP and DP, binary-coded decimal with variations and octal 0, 1, 2, 4 coded outputs. Internal lighting of readout and color coding of switch tabs are also available. Available in switch modules that permit ganging in any desired number. **Digitran Co, 660 S Arroyo Parkway, Pasadena, Calif.**

Circle 313 on Reader Service Card

Rotary multipole switch . . .

has solder-lug terminals with elongated hole to accommodate up to three No. 16 wires. Switch has max interrupting rating of 5 amp, 125 v ac and continuous-current rating of 10 amp. Can be furnished in variety of contact arrangements and from 1 to 10 sections. Designed for single-hole panel mounting. Measures 2$\frac{7}{32}$ in. dia and extends 1$\frac{1}{16}$ to 5¼ in. behind panel. **Electro Switch Corp, King Ave, Weymouth, Boston 88.**

Circle 314 on Reader Service Card

Hydraulic safety lock . . .

for high-pressure systems, installed at cylinder inlet, allows continuous fluid flow to and from cylinder without decreasing rate. In event that line break occurs, lock closes immediately, trapping fluid in hydraulic cylinder. Load can be lowered by turning allen setscrew, which gradually relieves pressure inside safety lock. **Ground Systems Inc, 9752 Cortada, El Monte, Calif.**

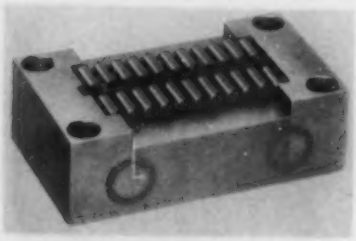
Circle 315 on Reader Service Card

Tubeless motor-speed controls

for use with ¼- and ½-hp shunt-wound motors require no warmup time. Full-wave control can be switched from forward to reverse at any motor-speed setting. Speed range is 18:1 at full rated motor torque. Motor speed is controlled by varying armature voltage with autotransformer. 16-ga gray steel case measures

5¾ x 9¼ x 9⅞ in., not including knob projections. Net weight is 16 lb. Models are available for 115 or 230 v, 60 cps input. **Minarik Electric Co, 224 E Third St, Los Angeles 13.**

Circle 316 on Reader Service Card



Roller-way cartridge . . .

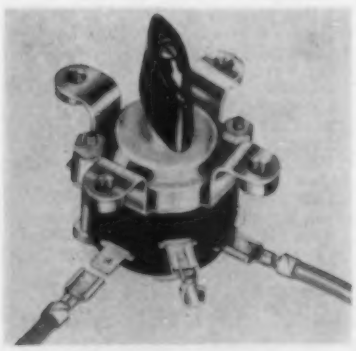
reduces break-away and drag friction in operation of machine-tool heads and tables. Available in four standard sizes. No screws are used in assembly. Finished cartridges are ground square on all surfaces for flush installation. **Beaver Precision Products Inc, Clawson, Mich.**

Circle 317 on Reader Service Card

Polyethylene coating resin . . .

is said to develop max adhesion to wide variety of substrates. Has density of 0.924; melt index of 3.0. Flow characteristics suited for high-speed extrusion coating. Coatings as thin as 0.5 mil can be applied. Resin is also reported to be 100% greaseproof. **US Industrial Chemicals Co, Div of National Distillers and Chemical Corp, 99 Park Ave, New York 16.**

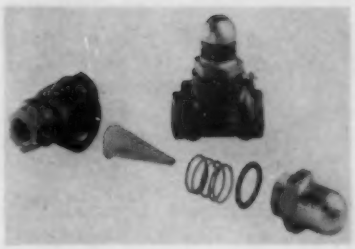
Circle 318 on Reader Service Card



Rotary power switch . . .

with male quick-connect terminals, is rated 10 amp. Terminals, which are integral with stationary contacts, can be furnished on any side-connected switches having either make-before-break or break-before-make contacts. **Electro Switch Corp, King Ave, Weymouth, Boston 88.**

Circle 319 on Reader Service Card



Strainer assembly . . .

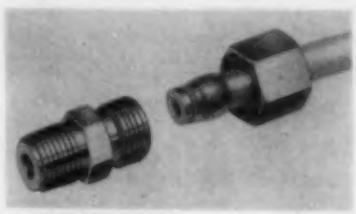
prevents chips and flakes from entering hydraulic control valves. Attaches before and after control valve. Specially designed inlet and outlet ports enable continuous flow through assembly with 100-mesh brass screen catching chips and flakes. Can be cleaned in field without removing unit from line. Operating temperature range is −70 to 275 F. Unit can handle pressures up to 3000 psi. **Ground Systems Inc, 9752 Cortada, El Monte, Calif.**

Circle 320 on Reader Service Card

Miniature cartridge heaters . . .

measure ⅛ in. dia in any desired length from 1 in. upward. Operated at max surface temperatures up to 1250 F. Can also be used as high-temp resistors, supplying up to 50 w per sq in. max density for electrical and electronic applications. Most voltages, including 115 and 230, are available. Also available in $\frac{5}{32}$ and ¼-in.-dia sizes. **Hotwatt Inc, 75 Maple St, Danvers, Mass.**

Circle 321 on Reader Service Card



Brass adapter . . .

is said to achieve leakproof seal between plastic tubing and standard compression-metal fitting. Regular compression nut is inserted on plastic tubing and adapter is inserted in end of tubing. Available for various sizes of tubing. **Robert Mfg Co, 9035 Venice Blvd, Los Angeles 34.**

Circle 322 on Reader Service Card

Push-to-test switchlight . . .

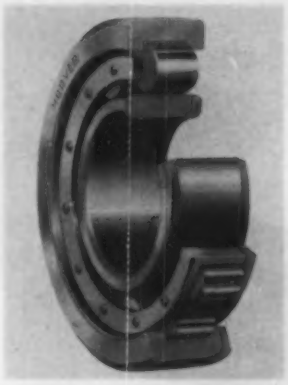
has lamp connected internally to arms of DPDT switch, enabling two separate circuits to be monitored without common connection. Switch contacts are rated 1 amp dc, resistive load, with life expectancy said to exceed 100,000 operations. Replaceable neon or incandescent lamps, with optional voltage ratings, can be supplied. **Eldema Corp, 1805 Belcroft Ave, El Monte, Calif.**

Circle 323 on Reader Service Card

Timers . . .

driven by synchronous motors, are fully enclosed in phenolic housing. Rated at 25 amp, 250 v ac, noninductive; ½ hp, 125 v ac at 50 and 60 cps. UL-approved for this rating. **Oak Mfg Co, 1260 Clybourn Ave, Chicago 10.**

Circle 324 on Reader Service Card



Cylindrical roller bearings . . .

are offered in three series in a complete range of sizes. Each series provides option of five variations—straight inner race, straight outer race, single-flanged inner race, single-flanged outer race, and single-flanged inner race with stabilizing ring. Bearings have crowned rollers. **Bearing Div, Hoover Ball and Bearing Co, 5400 S State Rd, Ann Arbor, Mich.**

Circle 325 on Reader Service Card

Axial-flow blower . . .

is said to develop pressures as high as 25 in. H_2O from 4-in.-dia axial-flow rotors. Drives available for 12, 28 and 110 v dc, 60- and 400-cps motors. **General Turbine Corp, 1338 West Ave, Buffalo 13, NY.**

Circle 326 on Reader Service Card

Miniature pressure switch . . .

responds to changing pressures in air, fuels, lubricants, gases or other media. Measures 1 x 1 in. dia; weighs less than ½ oz. Has operating range from 0 to 500 psi. Repeat accuracy is said to be within 0.5% of original setting, depending upon operating range. SPDT snap-action microswitch is rated for 6 amp, 125/250 v ac. Operates in temperatures from −65 to 300 F. Can be set without removing unit and while system is in normal operation. Designed

continued on page 68

to meet MIL-E-5272A; will take up to 100 g shock. **Pamar Electronics Co, 103 Marine St, Farmingdale, NY.**

Circle 327 on Reader Service Card

TFE-fluorocarbon O-rings . . .

are available in about 300 standard sizes, in uniform dash-numbering system for O-rings known as ARP-568. Suitable for use with any operating fluid. In addition to commercial surface finish, O-rings are available in mirror finish. **Chicago Gasket Co, 1271 W North Ave, Chicago 22.**

Circle 328 on Reader Service Card

Strap-type pillow blocks . . .

offer two-bolt mounting, automatically drawing cap into proper adjustment against base. Suitable for normal-duty applications. Three series are offered. **Randall Graphite Bearings Inc, Greenlawn Ave and Lake St, Lima, Ohio.**

Circle 329 on Reader Service Card

Immersion-heating elements

with offset thermostat wells, for temperature control setting are offered from stock in two series. One series, available in 118 or 236 v, with capacity of 2000 or 2500 w, has standard 1¼-in. IPS plug for all models. Second series, available in 118 or 236 v, with capacities from 500 to 1500 w, has 1-in. plug. **Coolerator Div, McGraw-Edison Co, Albion, Mich.**

Circle 330 on Reader Service Card

Elapsed-time indicator . . .

has decimal-type counter which provides readings from 000 to 999 hr with return to 000 in 1-hr increments. Over-all dia of indicator is 0.670 in.; length is 1⅞ in. Weighs about 1.8 oz. Nominal input is 115 v at 400 cps, single phase. Current is approximately 10 milliamp. Unit is

continued on page 70

SPHERCO® BEARINGS

If you have applications involving linkage or transfer of motion, SPHERCO Bearings can supply your needs in a wide variety of materials with a quality that will give you top performance under normal or high temperature conditions.

WRITE FOR BULLETIN 257

SPHERCO
A PRODUCT OF
SEALMASTER BEARING DIVISION
STEPHENS-ADAMSON MFG. CO.
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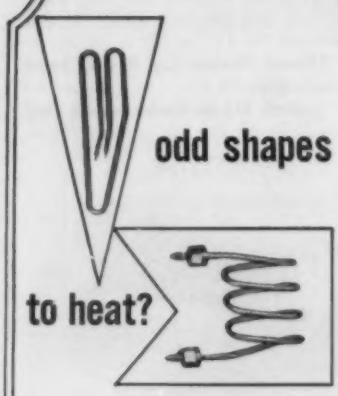

VULCAN TUBULAR HEATERS

Vulcan Tubular Heaters can be formed into an endless variety of unusual shapes to provide a lot of heat in a little space. They are easily cast into aluminum or other metals. They are ideal for immersion in liquids, soft metals or molten salts. Straight tubular heaters are readily clamped to metal surfaces or inserted in machined grooves. And they can be furnished with flattened surface for even more effective heat transfer.

Vulcan Tubular Heaters are available in a wide choice of lengths — 10″ to 185″ (special, shorter or longer); diameters — .250″; .280″; .333″; .450″; .496″; .540″; wattage — 10 to 10,000 (or higher); voltage — standard 120, 240 or 480; special 6 to 600 (or higher); sheaths — copper, steel, aluminum, high temperature alloys.

Write for catalog and prices.

VULCAN
Versatility in Electric Heating
VULCAN ELECTRIC COMPANY, Danvers, Mass.

AGAIN-

Shown here is the 6"
Rapidaytor
Dolphin Submersible Pump, one of a complete line of 4" and 6" pumps made by THE TAIT MANUFACTURING COMPANY, Dayton, Ohio. Arrow points to the upper body shell made of Revere seamless leaded brass tubing. Hand holds the diffuser casing made of Revere Brass Strip and used inside pump.

Revere helps "fit the metal to the job"

AND A PUMP MANUFACTURER FABRICATES SUPERIOR PARTS WITH GREATER EASE . . . INCREASES TOOL LIFE

An important part of the submersible pumps made by Tait Manufacturing Company is the brass diffuser casing you see above. This part had formerly been made of ferrous metal. While satisfactory as a pump part it was difficult to work and draw . . . at the same time tool life was short.

One of Revere's Technical Advisors was asked to study the problem. Revere Cartridge Brass Strip of a certain temper was recommended, samples submitted, and, after extensive tests, was approved. The customer has found that not only does the diffuser casing, made of Revere Brass, perform well in the pump, but it also has superior drawing properties, is more easily worked, and tool life has been substantially increased.

This meticulous attention to "fitting the metal to the job" also resulted in Tait Manufacturing Company's specifying Revere seamless leaded brass tubing for the upper body shell of its submersible pumps. Here the application called for extremely close straightness and roundness control which meant special attention to detail on the part of the Revere mills.

Why not put the extensive knowledge of Revere's T.A. Service to work for you? With the wide variety of metals at your disposal, perhaps Revere can help you select the one best suited for the job, with a resultant saving of money while improving product quality.

REVERE COPPER AND BRASS INCORPORATED

Founded by Paul Revere in 1801

Executive Offices; 230 Park Avenue, New York 17, N. Y.

Mills: Rome, N. Y.; Baltimore, Md.; Chicago and Clinton, Ill.; Detroit, Mich.; Los Angeles, Riverside and Santa Ana, Calif.; New Bedford, Mass.; Brooklyn, N. Y.; Newport, Ark.; Fort Calhoun, Neb.
Sales Offices in Principal Cities, Distributors Everywhere.

CIRCLE 69 ON READER SERVICE CARD

REDUCE MANUFACTURING COSTS

IMPROVE PRODUCT PERFORMANCE

SOLVE DESIGN PROBLEMS

with

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MOLDED ORGANIC PARTS

REDUCE COSTS

High-density molded organic part replaces brass pressure plate in clutch assembly

IMPROVE PERFORMANCE

Semi-flexible molded organic parts replace leather washers in deep well pump

SOLVE DESIGN PROBLEMS

Resilient molded organic part replaces combination metal-hard rubber vibration damper

● A fresh approach to design problems with WORLD BESTOS Molded Organic Parts can pay off in improved product performance and reduced manufacturing costs. Applications range from industrial and automotive equipment to home appliances. Molded Organic Parts can be built to meet virtually any shape, size or performance specifications. Parts can be supplied for testing and evaluation or on a production basis. For complete details, send samples or blueprints to WORLD BESTOS, New Castle, Indiana. Phone Jackson 9-4790.

WORLD BESTOS NEW CASTLE INDIANA

DIVISION OF THE Firestone TIRE AND RUBBER CO.

Industrial and Automotive Brake Blocks and Linings · Transmission Linings · Special Clutch Facings · Vibration Controls · Sheet Packing

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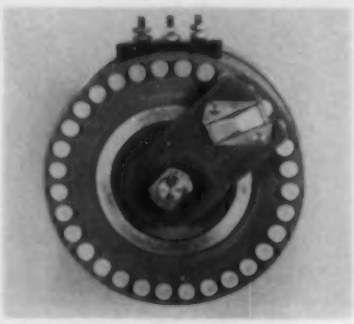
self-contained, including motor. Filled with inert gas and hermetically sealed. **Bowmar Instrument Corp, 8000 Bluffton Rd, Ft Wayne, Ind.**

Circle 331 on Reader Service Card

Miniature switchlight . . .

incorporates replaceable incandescent lamp with large plastic lens. DPDT snap-action switch is rated for 28 v dc, 7 amp resistive; 115/230 v ac, 60 cps, 5 amp resistive and inductive. Lamps are available with ratings from 1¼ to 48 v. Rated for 25,000 operations min. Said to meet or exceed all applicable military specifications. **Eldema Corp, 1805 Belcroft Ave, El Monte, Calif.**

Circle 332 on Reader Service Card



Miniature variable delay line

is lumped-constant line molded as integral part of 32-contact rotary switch. Heavy-duty contacts are said to provide positive repeatability and to eliminate time jitter. Each line in series comes in package 2.75 in. dia x 1.75 in. deep that weighs 14 oz. Six models have total delay times of 0.5, 1, 2, 5, 7, 7.5 and 10 microsec. Each line has 10:1 delay to rise time ratio at max delay. Characteristic impedance range from 100 to 500 ohm. Price, $125 for 1 to 4 units. Delivery, 2 to 4 wk. **Valor Instruments Inc, 13214 Crenshaw Blvd, Gardena, Calif.**

Circle 333 on Reader Service Card

Rack-and-panel connectors . . .

are self-aligning even when using commercial tolerances. Cylindrical rack-and-panel plugs are available in 7 to 61 shell sizes, with bonded-in or snap-in contacts. Rectangular rack-and-panel units come in 49

continued on page 71

and 99 shell sizes, with snap-in contacts, and utilize silicone and hard plastic materials for insert sandwich. Operate at altitudes to 110,000 ft and temperatures from —67 to 300 F. **Deutsch Co, Electronic Components Div, Municipal Airport, Banning, Calif.**

Circle 334 on Reader Service Card

All-purpose pushbutton switch

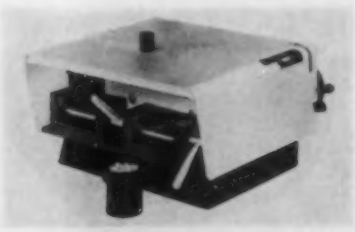
has recessed, knurled face nut to prevent button from being accidentally kicked in. Available from stock. Accommodates 6-, 12- and 24-v systems. Unit has silver inlaid contacts and contactors, and is weatherproof. Button and face nut are chrome-plated. Switches are 2 x 1¼ in. wide. Mounting stem is ¾ in. dia. Weighs 0.18 lb. **Cole-Hersee Co, 20 Old Colony Ave, Boston.**

Circle 335 on Reader Service Card

Silicon power rectifier . . .

of double-diffused type is rated 13 amp average at 77 F ambient on 3 x 3 x ⅛-in. copper heat sink. Standard and reverse polarity are achieved through double diffusion. Typical forward dynamic resistance is 0.009 ohm. **Syntron Co, 240 Lexington Ave, Homer City, Penna.**

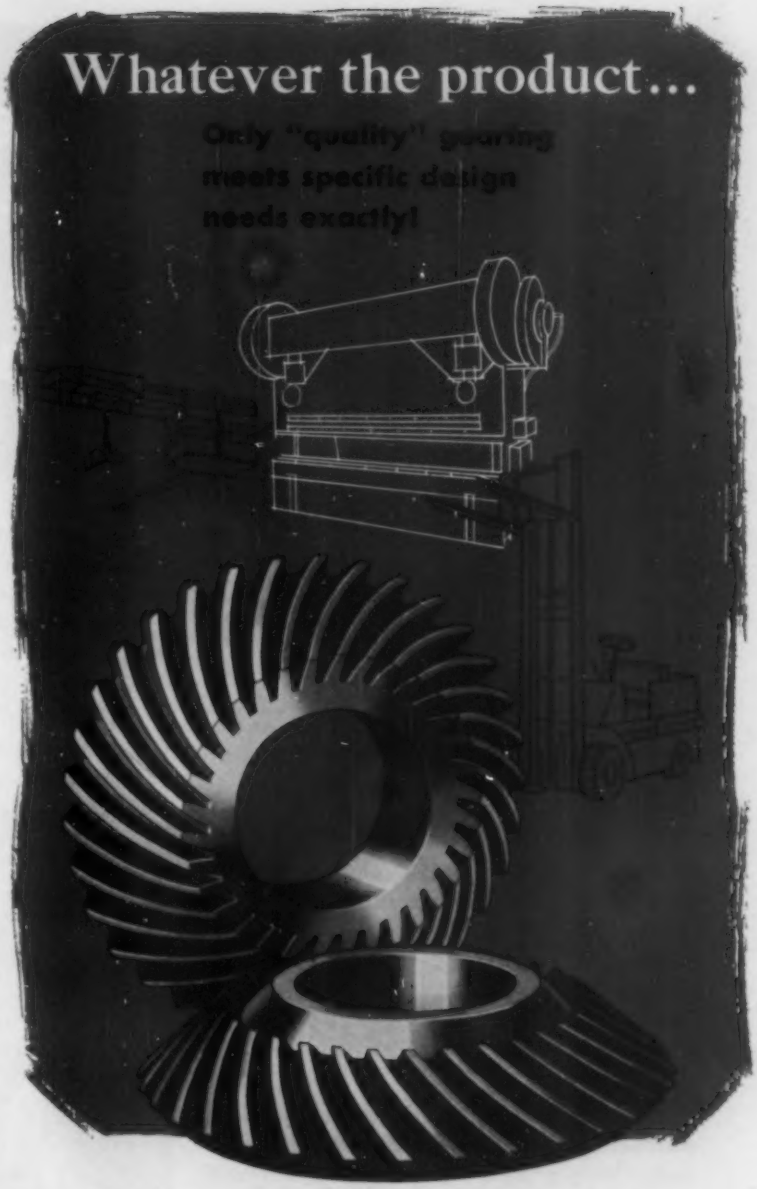
Circle 336 on Reader Service Card



Instrument tells true volume . . .

as well as density, specific gravity or porosity of solid materials, whether they be porous, granular, powdery or irregular in form. Based upon principle that two closed systems of air at the same pressure and temperature will have identical specific volumes, instrument allows direct digital indication of true or absolute volume of any solid substance with 1-min. procedure. Sample of material is placed in container, crank is turned until forcefully stopped, then second crank is turned

continued on page 75



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CIRCLE 71 ON READER SERVICE CARD

DODGE HAS MORE PROVED BEARINGS THAN YOU HAVE BEARING PROBLEMS!

It pays to buy from a line of stock bearings—bearings that have been proved in thousands of installations similar to yours. You benefit by getting known dependability; and you get the important savings of high quality at production price.

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Dodge has supplied mounted bearings to industry for over three-quarters of a century. Dodge bearings have always kept pace with improved production practices. Each new condition of service has been met by Dodge as it has arisen, with the result that the Dodge line contains mounted bearings to meet almost every service requirement with pin-point accuracy.

High load, high speed, excessive dust, moisture, corrosion, high or low temperatures, continuous operation—you name it!—such conditions and their combinations are met every day with Dodge bearings.

BROAD LINE—WIDELY DISTRIBUTED

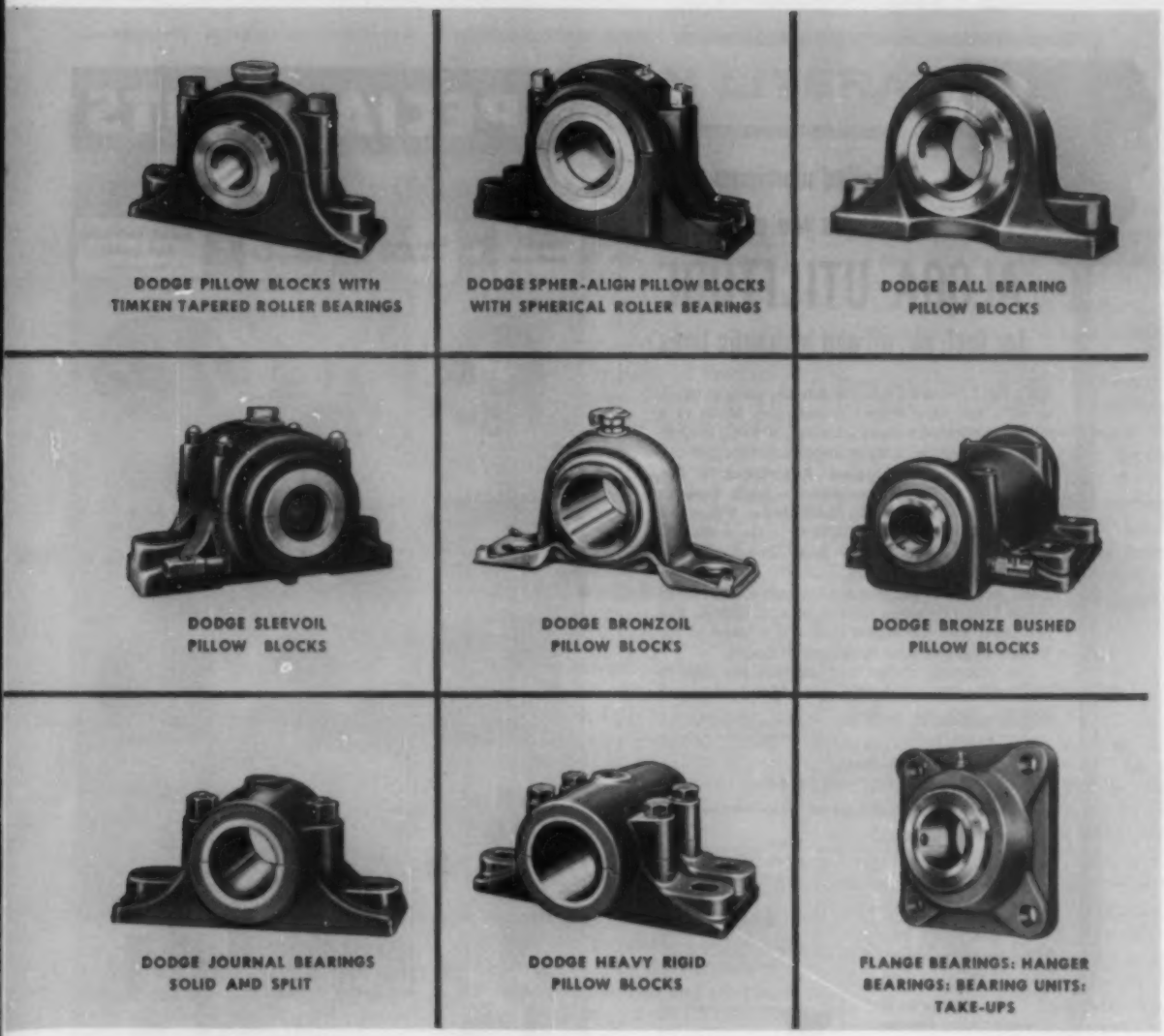
In the great variety of mounted bearings developed by Dodge, you will most likely find the precise unit to fit your requirements ideally—without paying for features you do not need. And if your requirements call for several types of bearings, there is an advantage in having them of common design, such as Dodge offers.

The Dodge line is probably broader than any other line of mounted bearings in America. And of special importance to machinery manufacturers, it is the most widely distributed line. There is always a Dodge bearing of the right type and size near at hand.

You can check this with your local Dodge Distributor. Ask him—or write us for the Dodge Bearing Bulletin.

In addition to tapered roller, spherical roller and ball bearings, Dodge builds many types of sleeve bearings. Here is the "large and small" of the sleeve type bearings carried in stock—ranging from an 8-in. Sleevoil weighing over 1200 lbs. to a ½-in. solid journal bearing weighing 9 ounces.

DODGE MANUFACTURING CORPORATION, 1200 Union Street, Mishawaka, Indiana


DODGE PILLOW BLOCKS WITH TIMKEN TAPERED ROLLER BEARINGS
DODGE SPHER-ALIGN PILLOW BLOCKS WITH SPHERICAL ROLLER BEARINGS
DODGE BALL BEARING PILLOW BLOCKS
DODGE SLEEVOIL PILLOW BLOCKS
DODGE BRONZOIL PILLOW BLOCKS
DODGE BRONZE BUSHED PILLOW BLOCKS
DODGE JOURNAL BEARINGS SOLID AND SPLIT
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FLANGE BEARINGS: HANGER BEARINGS: BEARING UNITS: TAKE-UPS

● **Dodge Pillow Blocks with Timken Tapered Roller Bearings.** America's quality pillow blocks. Assembled, lubricated, adjusted and sealed at the factory. 5 types for varying needs.

● **Dodge Spher-Align with Spherical Roller Bearings.** Rugged heavy duty, compact, inherently self-aligning. Exclusive Micro-Mount simplifies installation.

● **Dodge Ball Bearing Pillow Blocks.** Deep groove ball bearings with long inner races—high capacity. SL, SC and SCM models for light, normal and medium service respectively.

● **Dodge Sleevoil Pillow Blocks.** Ultra quality . . . extra long life . . . accessibility . . . *quiet*. Plain or water-cooled.

● **Dodge Bronzoil Pillow Blocks.** Efficient, low cost pillow blocks with self-oiling, capillary bronze bushings. Self-aligning. Large oil reservoirs.

● **Dodge Bronze Bushed Pillow Blocks.** Quiet fan and blower pillow blocks with two bronze bushings of high lead content mounted in one cast iron housing.

● **Dodge Journal Bearings — Solid and Split.** True running, dependable. Babbitted bearings with precision machined bores and faces. Finished bases.

● **Dodge Heavy Rigid Pillow Blocks.** Rugged, carefully bored, babbitted pillow blocks for many applications requiring grease lubrication. Finished bases and ends.

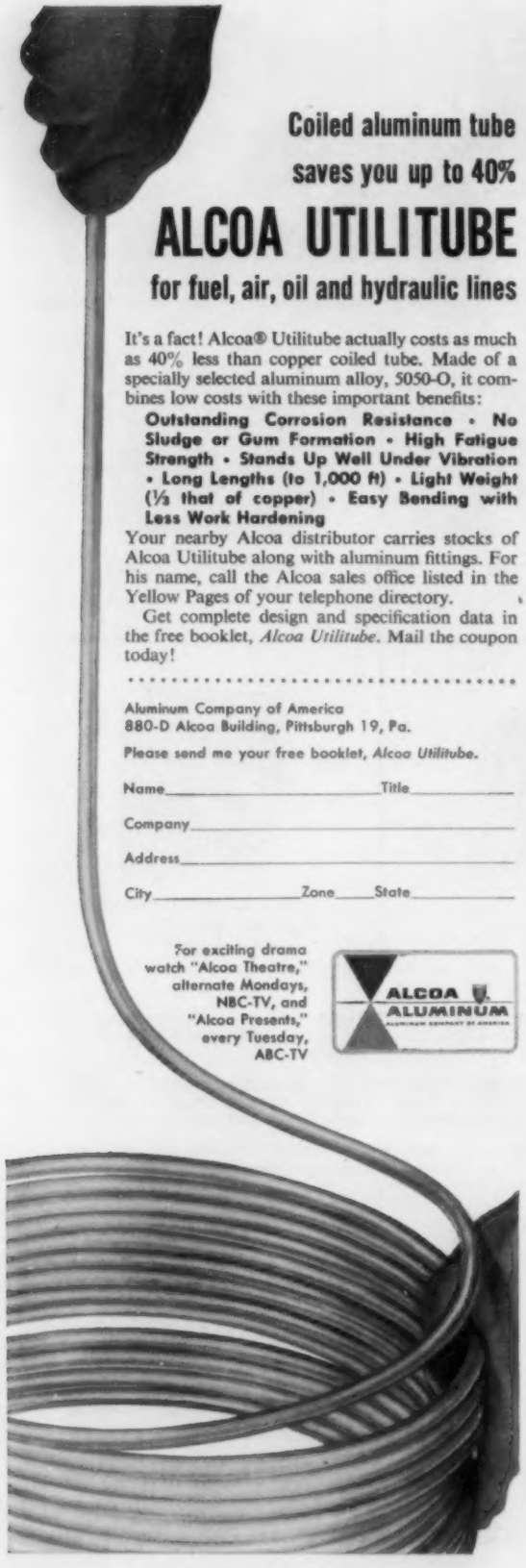
● **Bearing Units.** A wide variety—spherical seat, cartridge, flange, hanger, screw conveyor hanger, take-up. Ball, Roller and Sleeve types.

CALL THE TRANSMISSIONEER—your local Dodge Distributor. Factory trained by Dodge, he can give you valuable help on new, cost-saving methods. Look under "Dodge Transmissioneer" in the *white* pages of your telephone directory, or in the yellow pages under "Power Transmission Machinery."

DODGE

of Mishawaka, Ind.

CIRCLE 73 ON READER SERVICE CARD 73



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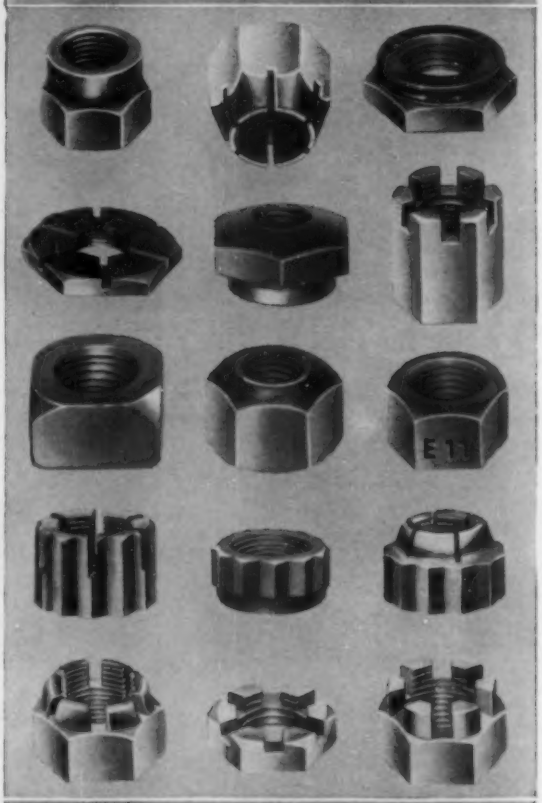
SPECIAL NUTS

to specs. 3/8" - 4-1/4" cross flats

special machines + large stock of material × years of experience = speedy deliveries high quality low prices



Here are a few samples made to customers specifications . . Our batteries of special high-speed multi-spindle, automatic machines make possible fast and accurate production of hexagon nuts of non-standard height and special shape from carbon or alloy steel, Naval bronze or other non-ferrous metals; also AN 310 through AN 335 as per latest Airforce specifications. Very often the special nut you require may be similar to one we are already making and a simple modification would result in a price advantage and quicker deliveries to you . . Send us your blueprint and particulars —let us quote on your requirements . . We also have a catalog that contains complete specifications, engineering data and prices regarding our standard nuts.

Manufacturer of Standard and Special
12 Pointer, Square and Hexagon Nuts
. . . "Huglock" and "Conelok" locknuts.

NMP

NATIONAL MACHINE PRODUCTS COMPANY

an SPS company 44250 UTICA ROAD
UTICA, MICH

until gage reads zero. Volume can then be read directly from digital readout in terms of cc or cu in. For field, laboratory or factory usage. Initial instrument will have choice of 50-cc or 100-cc sample containers. Accuracy is said to be 0.1 cc with 50 cc cup. Model 200 is $450, FOB Houston. Available in 30 days. **Houston Instrument Corp, PO Box 22234, Houston 27.**

Circle 337 on Reader Service Card

High-speed microfilm machine

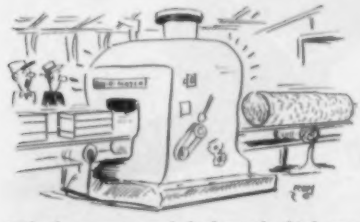
continuously feeds drawings from pile, registers them, conveys them under camera, adjusts illumination to proper level, photographs drawings and discharges them to delivery pile. Sheets, up to 22 x 34 in., are handled by the machine, as are roll drawings up to 42 in. wide. Microfilms up to 1200 drawings per hr. Camera accommodates 1000-ft rolls of 35 mm film. **de Florez Co Inc, 200 Sylvan Ave, Englewood Cliffs, NJ.**

Circle 338 on Reader Service Card

105-, 35-mm camera-projector

offers motor-driven projector magazine that changes negatives automatically; motorized filter built into optical system; automatic control of point-source light; projector that holds 35-mm roll film under vacuum during exposure; interruption of filming sequence to shoot single frame of any size and immediate development without loss of film; 44 x 64-in. subject area that covers 42-in. tracings. Design is said to simplify magazine loading of film. **Keuffel & Esser Co, Third and Adams Sts, Hoboken, NJ.**

Circle 339 on Reader Service Card



"The boss was worried about the high cost of production, until the Engineering Dept. came up with this."

DESIGN LITERATURE

An Outline of United States Patent Laws

BRINK, GIPPLE, HUGHESDON. Interscience Publishers Inc, 250 Fifth Ave, New York 1. 6 x 9, 280 pp. $7.50.

The fundamental sources of all US patent law are the two legal documents, "Title 35 of the United States Code" and "The Rules of Practice of the United States Patent Office in Patent Cases." These two documents, reprinted in full, form the appendix and the major portion of the text of this book. The authors' contribution is an outline, comprising the first third of the book, in which the facts to be found in these legal documents are unscrambled, rearranged, amplified and annotated. They discuss, in order: definition of a patent, preparing and filing, interference, rights, infringement. Not a readable book, this reference work will help the engineer answer specific questions about patent law.

Reactive Metals

Edited by W R CLOUGH. Interscience Publishers Inc, 250 Fifth Ave, New York 1. Volume 2: 7 x 10, 610 pp. $15.

The reactive metals are not limited to the nuclear materials. They also include the lightweights for moderate temperatures—titanium and vanadium, and the refractory metals for extremely high temperatures—columbium, molybdenum, tantalum, rhenium and tungsten.

This collection of technical papers presents physical- and mechanical-property data for the more significant alloys now emerging from research laboratories. It also gives design criteria for producing parts from these materials. The papers were presented at the Third Annual Conference sponsored by Niagara Frontier Section in cooperation with The Metallurgical Society, American Institute of Mining, Metallurgical, and Petroleum Engineers, Buffalo, NY, May 27-29, '58.

Mathematical Analysis

EDWIN M HEMMERLING, Chairman, Science, Engineering and Mathematics Div, Bakersfield College. McGraw-Hill Book Co Inc, 330 W 42nd St, NY 36. 6 x 8½, 332 pp. $5.75.

A mature approach, emphasizing throughout the meaning of concepts and crystal-clear explanations and illustrative examples, makes this text ideal for a review book for engineers who have been out of touch with math since college days.

The text begins with fundamental algebraic equations and goes through elements of differential calculus. The function concept is given more attention than is usually found at this level. Special emphasis is placed upon the analytic relationship between trigonometric functions rather than on the solution of triangles. Radian measure is given extensive treatment. Inverse-function notation is frequently noted, with stress upon the inverse relationship between exponential and logarithmic functions.

The Science of Mechanics in the Middle Ages

MARSHALL CLAGETT. University of Wisconsin Press, Madison, Wis. 6¾ x 10¾, 711 pp. $8.

Galileo's name is the first to come to mind when we think of scientists of the middle ages; actually, Galileo was one of the last scientists of the period. This treatise includes 45 documents comprising the most important passages from the works of medieval mechanics up to and including Galileo. Clagett covers the influence of the Greek and Arabic scientists, kinematics and dynamics. Some of the text is in Latin; however the author has taken care to provide a translation in most cases. If you're looking for a reference book in the field of medieval mechanics, Clagett has provided the source.

Other Books of Interest

Properties of Certain Cold-Rolled Austenitic Stainless Sheet Steels

PB 151069. Mangone, Roach & Hall. Office of Technical Services, Dept of Commerce, Washington 25, DC. 8½ x 11, 62 pp. $1.75.

Includes Type 201,301, USS Tenelon, USS 17-5 MnV.

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Allen C Wilson. McGraw-Hill Book Co Inc, 330 W 42nd St, New York 36. 6 x 9½, 295 pp. $9.

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Society of the Plastics Industry Inc, 250 Park Ave, New York 17. 6 x 9, 208 pp. $5.

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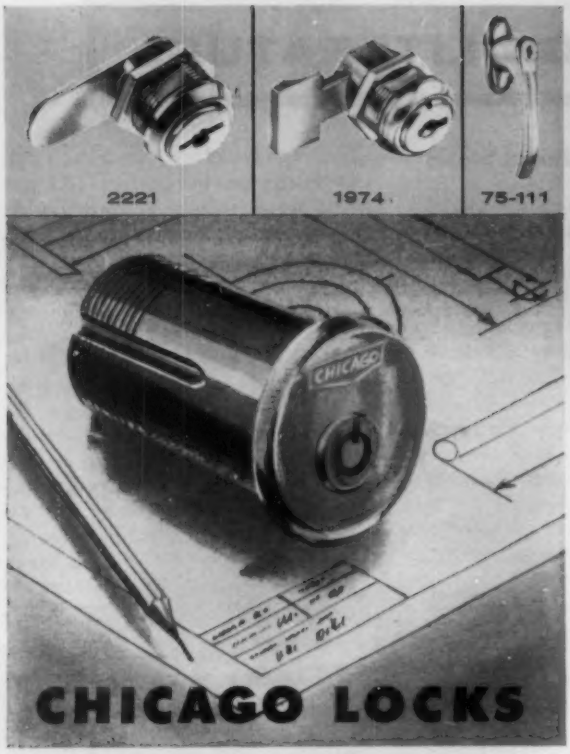

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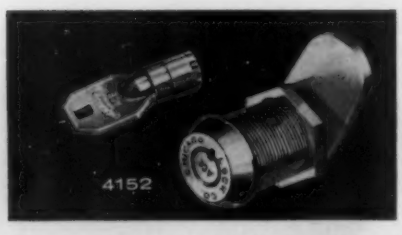

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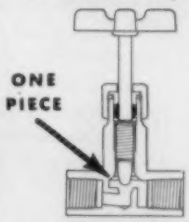

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NASA TN D-256. Lie and Corten. National Aeronautics and Space Administration, Washington, DC. 7¾ x 10¼, 56 pp. $1.50.

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R D Carmichael. Dover Publications Inc, 180 Varick St, New York 14. 5⅛ x 8, 118 pp. $1.35.

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"Rolling Friction of Polymeric Materials," Donald G. Flom, General Electric Research Laboratory. Journal of Applied Physics, Feb '60, 335 E 45th St, New York 17.

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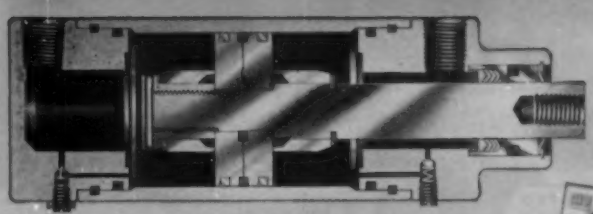

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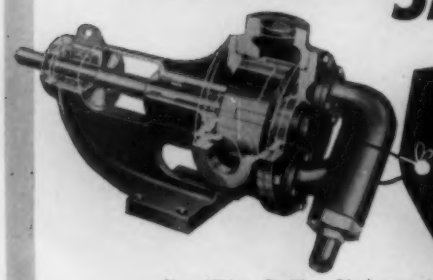

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"Rolling Curves and Noncircular Gears," W. H. Sheppard. Mechanical World and Engineering Record, Jan '60, 31 King St W 3, Manchester, England.

CATALOGS AND BULLETINS

To obtain copies of literature described below, circle corresponding number on postcard inside back cover.

HIGH-SPEED INDEXING COMPONENTS—Catalog 160, 40 pp. Compilation of standard roller-gear drive indexing mechanisms, high-speed precision index tables, in-line transfer machines and allied equipment. With load ratings, dimensions, installation data. Ferguson Machine Corp, 7818 Maplewood Industrial Court, St Louis 17.

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SPEED REDUCERS—Bulletin A692, 64 pp. Covers shaft-mounted units in range of sizes and hp, reducers for flange mounting, vertical shafts, right-angle drives and screw conveyor drives. With construction information, dimensions, prices and installation data. Dodge Mfg Corp, Mishawaka, Ind.

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STOCK ROLLER CHAINS, SPROCKETS—Book 2757, 44 pp. Presents over 2000 stock types and sizes. An 18-page section covers standard roller chains; 20-page section describes sprockets. Link-Belt Co, Dept PR, Prudential Plaza, Chicago 1.

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FASTENERS FOR ELEVATED-TEMPERATURE SERVICE—Engineering catalog 286, 24 pp. Describes and illustrates fasteners rated for applications at 1300 to 1800 F. Drawings indicate dimensions, material characteristics and head types. Mercury Air Parts Co Inc, 9310 W Jefferson Blvd, Culver City, Calif.

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PRECISION INSTRUMENT SWITCHES—Catalog, 28 pp. Presents mechanical dimensions, specifications, terminal-board reference charts and product descriptions. Cinema Engineering Div, Aerovox Corp, 1100 Chestnut St, Burbank, Calif.

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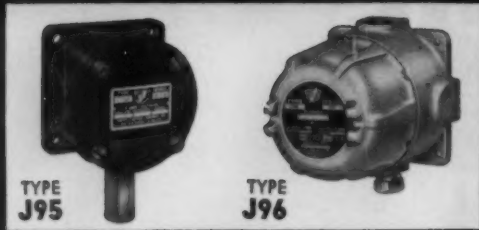

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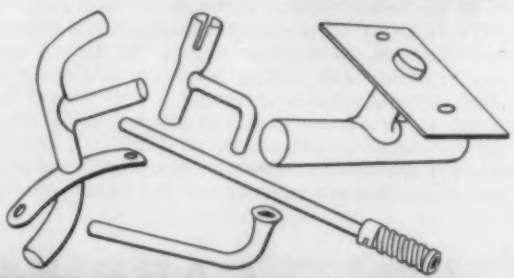

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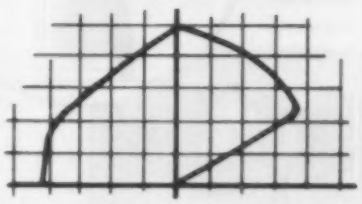

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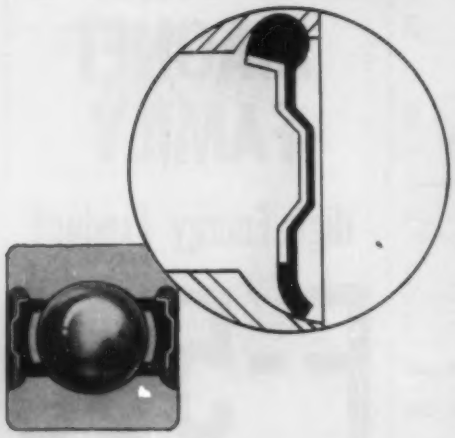

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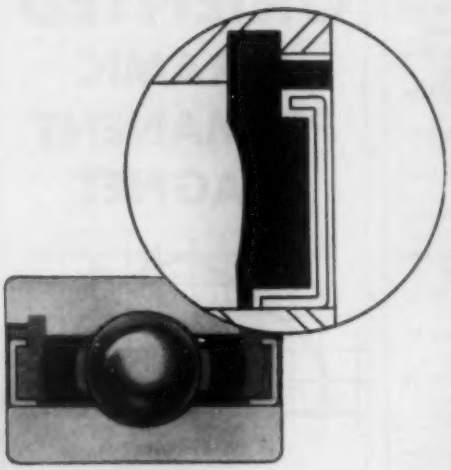

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361—Cobalt-tungsten Alloy, 4 pp, Waimet Alloys Co.

POWER TRANSMISSION

350—High-speed Indexing Components, 40 pp, Ferguson Machine Corp.

351—Speed Reducers, 64 pp, Dodge Mfg Corp.

368—High-speed Indexing Drives, 2 pp, Geneva Motions Corp.

369—V-belts, 1 p, Browning Mfg Co.

MECHANICAL PARTS

352—Stock Roller Chains, Sprockets, 44 pp, Link-Belt Co.

358—Stock Knobs, 8 pp, American Meter Pump Div.

359—Steel Tubing, 8 pp, Ohio Seamless Tube Div, Copperweld Steel Co.

366—Bellows Rotary Seals, 4 pp, Hydrodyne Corp.

FASTENING AND JOINING

353—Fasteners for Elevated-temperature Service, 24 pp, Mercury Air Parts Co.

360—Adhesives and Laminating Materials 6 pp, Narmco Resins & Coatings Co.

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300—Fully Molded, Jacketed, Notched V-belt

304—Floating Right-angle Gear Drive

325—Cylindrical Roller Bearing

MECHANICAL PARTS

302—Subminiature Limit Switch

311—Vibration-proof Battery Holders

317—Roller Way Cartridge

326—Axial-flow Blower

328—TFE-fluorocarbon O-rings

MOTORS, ENGINES AND CONTROLS

316—Tubeless Motor Speed Controls

ELECTRICAL, ELECTRONIC COMPONENTS

305—Add-subtract Pulsing Device

306—Oiltight Limit Switches

312—Mercury Wetted Contact Relay

313—Modular In-line Switch

314—Rotary Multipole Switch

319—Rotary Power Switch

321—Miniature Cartridge Heaters

323—Push-to-test Switchlight

324—Timers

327—Miniature Pressure Switch

330—Immersion Heating Elements

331—Elapsed-time Indicator

332—Miniature Switchlight

333—Miniature Variable Delay Line

334—Rack-and-panel Connectors

335—All-purpose Pushbutton Switch

336—Silicon Power Rectifier

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301—Low-flow Regulator

303—Pressure Controller

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356—Size 18 Servomotors, 16 pp, Helipot Div, Beckman Instruments Inc.

364—Controlled-speed Systems, 8 pp, US Electrical Motors Inc.

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365—Speed Measurement by Toothed Disk, 4 pp, Electro Products Labs Inc.

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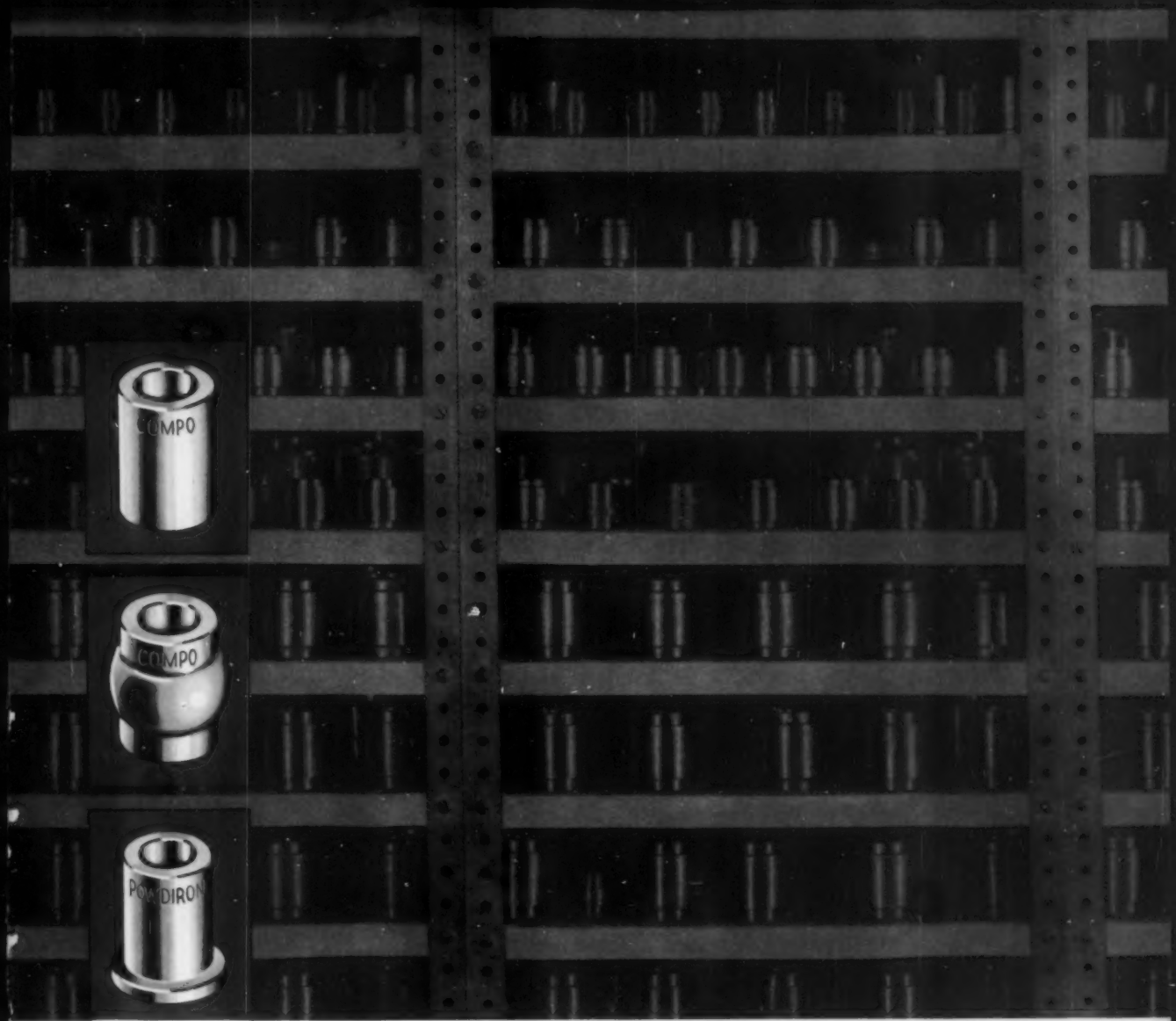

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